| | Article Title | Author/ Year | Level of Evidence** | Relevance to Capstone | Methods | Results | Conclusions |
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| 1. | Sport Specialization and Coordination Differences in Multisport Adolescent Female Basketball, Soccer, and Volleyball Athletes | DiCesare, C. (2019) | Cohort Study | High | Data was collected from a total of 1116 adolescent female basketball, soccer, and volleyball athletes. Participants were enrolled in 1 of 2 studies—a prospective cohort study to detect biomechanical deficits associated with anterior cruciate ligament injury or a randomized clinical trial to deliver neuromuscular training to improve these deficits—that were administered over 4 years. Participants were recruited and tested before the beginning of their respective competitive sport seasons. At the beginning of each testing session, participants' anthropometric, demographic, and self-reported | The sport-specialized group exhibited increased coupling variability in dominant-limb hip flexion and knee flexion, knee flexion and knee abduction, and knee flexion and knee internal rotation while landing during the drop vertical jump (DVJ), although they had small effect sizes. No differences were present between groups for any of the other CAV measures of the dominant limb, and no differences were found for any CAV measures of the nondominant limb. | Sports specialization group correlated with an increase in dominant limb coupling-angle variability (CAV) of hip-flexion and knee-flexion coupling, knee-flexion and knee-abduction coupling, as well as slightly increased variability in the knee-flexion and knee–internal rotation coupling compared to non-specialized group. This may lead to less stable hip-coordination and knee coordination patterns during landing and may ultimately lead to less efficient or more risky biomechanical outcomes. This can be increasingly detrimental to prepubertal/ pubertal adolescents with musculoskeletal immaturity from sporadic growth in bone mineral density and muscular/connective tissue strength. This may less optimally equip them to handle non-variable or repetitive stress impacting effective landing strategies that modulate GRF. This may lead to unstable landings, inefficient force-absorption strategies, or greater contact forces increasing MSK injury risk. Evidence supports all youth athletes befitting from guided S&C to prepare for demands of competitive sport participation. Youths who participate in ESS should incorporate deliberate training (S&C) to integrate neuromuscular training to enhance diverse motor-skill development and |

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| | | | | | measures of maturational status (eg, menses status) and sports participation were recorded. In addition, each athlete's dominant leg was determined by asking which leg she would prefer to use to kick a ball the farthest distance possible. Participants were excluded if they were not enrolled in a school-sponsored basketball, soccer, or volleyball team. Only participants with acceptable-quality 3-dimensional motion data and less than 2 years' involvement in at least 1 organized sport were included, leaving 938 participants available for further analysis. | | help reduce the potential for coordinative deficits.<br>Goal is to learn how maturation process affects youth athletes to know when adolescent athletes can safely specialize in sport. If adopted at an appropriate time during maturation, sport specialization can lead to skill improvement and refinement in that sport and, subsequently, greater potential for achievement—the intended goal of ESS, more safely monitored. |
| 2. | Sport specialization, part I: does early sports specialization increase negative outcomes and reduce the opportunity for success in young athletes? | Meyer, GD (2015) | Evidence Acquisition: Nonsystematic review.<br>Study Design: Clinical review.<br>Level 4 Evidence | Moderate | Clinical review of best evidence performed. | Year-round training specialized to a single sport can be a risk factor for various issues, and parents and coaches need to be cautious about encouraging early sport specialization in youth. 3components that define early sports | Athletes who met the definition of a highly specialized athlete had 2.25 greater odds of having sustained a serious overuse injury than an unspecialized young athlete, even when accounting for hours per week sports exposure and age. ESS may not allow youth athletes diversity of movement and decreases neuromuscular skill development and may not allow for the necessary rest from repetitive use of the |

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| | | | Consensus, disease-oriented evidence, usual practice, expert opinion, or case series.<br><br>Low-moderate evidence | | | specialization include year-round training (>8 months per year), choosing a single main sport, and quitting all other sports to focus on 1 sport. Increased degree of specialization is positively correlated with increased serious overuse injury risk. Some of the current literature regarding the relationship between sport specialization and injury (ie, association does not equal causation) could simply be a marker for excessive training volume in youth. The volume of training defined by hours per week of organized sports can increase injury risk either by exceeding 16 hours per week of organized sports or hours per week of organized sports greater than the athlete's age. Specialized young athletes may be at increased risk for injury since they may be more likely to participate in year-round training and may be involved in individual sports that | same segments in the body, which both increase injury risk. Year-round exposure to a single sport may be one of the primary reasons for injury risk in specialized athletes. Technical skilled sports typically require higher volumes of training in prepubescent stages for skill acquisition. ESS can lead to psychological burnout. Psychological readiness to return to sport after an injury does not always correspond with physical readiness. *Clinical recommendations table at end.* |

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| | | | | | | require the early development of technical skills. Adults involved in instruction of youth sports should be vigilant about noting any signs of stress, burnout, and physical symptoms in these athletes and be prepared to take corrective action such as backing off training intensity and frequency. | |
| 3. | Sports specialization and intensive training in young athletes | Brenner, JS (2016) | Clinical Report/ Review of current literature<br><br>Low to moderate | moderate | Literature review of best evidence performed by author and American Academy of Pediatrics. | See methods and conclusion sections.<br>Recommendations:<br>The primary focus of sports for young athletes should be to have fun and learn lifelong physical activity skills. Participating in multiple sports, at least until puberty, decreases the chances of injuries, stress, and burnout in young athletes. For most sports, specializing in a sport later (ie, late adolescence) may lead to a higher chance of the young athlete accomplishing his or her athletic goals. Early diversification and later specialization | Delayed specialization till late adolescents may increase likelihood of success of intended goals of athletes (increased sport-specific skills, playing beyond HS). Recommends youth sports because they provide: lifelong PA skills, socialization with peers, teamwork, and leadership skills, and improves self-esteem. Actual incidence of overuse/ overtraining injuries hard to fully assess due to lack of uniformity in literature on definitions used to describe, same with lack of uniformity of description on what ESS is. Increased prevalence of travel leagues as young as 7 years old increasing prevalence of ESS. Long term athlete development (LTAD) programs created to help youth athletes develop physical literacy: mastering of fundamental movement and sport-related skills. LTAD hierarchal model—empirical evidence only, not individualized. Early specialization programs focus on short-term benefits of youth sport success rather than |

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| | | | | | | provide for a greater chance of lifetime sports involvement, lifetime physical fitness, and possibly elite participation. If a young athlete has decided to specialize in a single sport, discussing his or her goals to determine whether they are appropriate and realistic is important. This discussion may involve helping the young athlete distinguish these goals from those of the parents and/or coaches. It is important for parents to closely monitor the training and coaching environment of "elite" youth sports programs 14 and be aware of best practices for their children's sports. Having at least a total of 3 months off throughout the year, in increments of 1 month, from their sport of interest will allow for athletes' physical and psychological recovery. Young athletes can remain active in other activities to meet | diversifying activities to meet long-term needs of child through enjoyment and variable play. **Early diversification increases potential for minimizing dropouts, maximizing sustained participation, fostering positive peer relationships and leadership skills, and creating intrinsic motivation through participation in enjoyable activities**. Screen for female athlete triad ((low energy availability, menstrual dysfunction, and low bone mineral density) in female youth athletes participating in intense PA programs. **Current studies show that NCAA athletes are more likely to have played multiple sports in HS, and that their first organized sport played was different from their current competitive sport in college.** For most sports**, late specialization with early diversification** is most likely to lead to elite status. Current evidence suggests that delaying sport specialization for most sports until after puberty (late adolescence, ~15 or 16 years of age) may minimize the risks of overload injuries. Early diversification allows the athlete to explore a variety of sports while growing physically, cognitively, and socially. ESS risk of injury is multifactorial, including training volume, competitive level, and pubertal maturation stage. |

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| | | | | | | physical activity guidelines during the time off. Young athletes having at least 1 to 2 days off per week from their sport of interest can decrease the chance for injuries. Closely monitoring young athletes who pursue intensive training for physical and psychological growth and maturation as well as nutritional status is an important parameter for health and well-being. | |
| 4. | Sports specialization in young athletes: evidence-based recommendations | Jayanthi, N (2013) | Literature review: inconsistent or limited-quality patient-oriented evidence<br><br>Low-moderate | Moderate | PubMed and OVID were searched for English-language articles from 1990 to 2011 discussing sports specialization, expert athletes, or elite versus novice athletes, including original research articles, consensus opinions, and position statements. | For most sports, there is no evidence that intense training and specialization before puberty are necessary to achieve elite status. Risks of early sports specialization include higher rates of injury, increased psychological stress, and quitting sports at a young age. Sports specialization occurs along a continuum. Survey tools are being developed to identify where athletes fall along the spectrum of specialization. | A survey of elite young athletes (Training of Young Athletes Study) found that parents were the strongest influence on the initiation of a sport while coaches were the strongest influence on their decision to perform intense training. The distinction of sports specialization should really be focused on children who commit exclusively to a sport during the early-to-middle elementary school years. Sports specialization may be better defined along a continuum, due to the fact some athletes who perform large volumes of intense training in a single sport throughout the year, while also participating in one or more additional sports—same principle without singular sport participation. The most relevant factor linking ESS, and injury rates seen by Pediatricians is whether they have quit other sports to focus on 1 sport, |

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| | | | | | | Some degree of sports specialization is necessary to attain elite-level skill. However, for most sports, intense training in a single sport to the exclusion of others should be delayed until late adolescence to optimize success while minimizing risk for injury and psychological stress. | which accounted for 38% of the variance in the sport specialization score. The second-most relevant factor, 32% of the variance, was whether the child had spent more than 3 quarters of their training time in 1 sport. Study of 519 US Tennis Association junior tennis players found that 70% began specializing at an average age of 10.4 years old. There is general agreement that the number of hours spent in deliberate practice and training positively correlates with level of achievement in both individual and team sports; whether this intense practice must begin during early childhood and to the exclusion of other sports is a matter of debate. **Research in athletes has not consistently demonstrated that early intense training is essential for attaining an elite level in all sports (Table 1**). World-class athletes were more likely to start competing at a later age and competed in other sports. A recent survey of 148 elite and 95 near-elite Danish athletes (mean age, 24.5 years; track and field, weightlifting, cycling, rowing, swimming, skiing) found that the elite group began intense training at a later age and spent fewer hours practicing its main sport up to the age of 15 years compared to the near-elite group. By 18 years of age, the 2 groups had accumulated a similar number of practice hours, but by 21 years, elites had accumulated more practice hours. Early diversification is more likely to lead to success (Table 1). Early diversification provides the young |

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| | | | | | | | athlete with valuable physical, cognitive, and psychosocial environments and promotes motivation. Among high-level athletes, the greater the number of activities that the athletes experienced and practiced in their developing years (ages 0-12 years), the less sports-specific practice was necessary to acquire expertise in their sport. Increased exposure/ training volume may the most important risk factor for injury-- significantly elevated risk once training volume exceeded 16 hours per week (Figure 1). Peripubertal gymnasts are more likely injured during periods of rapid growth. ESS may contribute to burn out and dropping out of sport. |
| 5. | When is it too early for single sport specialization? | Feeley, BT (2016) | Clinical Report/ Review of current literature<br><br>Low to Moderate | High | Literature review of best evidence performed by author and American Journal of Sports Med. | See Conclusions section.<br><br>Overuse sports injuries in youth athletes often relate to musculoskeletal and physiologic immaturity—can lead to increased risk for injury with increased training volume. (Table 3 pg 4)<br><br>Recommendations across sports are not based on high-level published evidence, nor is there published evidence that rates of injury have decreased with these limitations. | Recently seen a recent increase in the number of year-round travel leagues for preadolescents. Over the past 20 years, there has been a shift in emphasis from youth-driven recreational sports activities to parent and coach-driven skills development with an emphasis on achieving a high level of accomplishment in a single sport--parents are often driving influence on initiation of sports, coach may be primary driving influence on the decision to specialize in a single sport. In one study, they found that elite athletes had spent less time in intense training than the nonelite athletes. However, by age 21, the elite athletes had accumulated more time in training in their main sport. The authors concluded that late specialization as the athlete reaches physical maturity might be more likely to result in elite status. |

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| | | | | | | (See USA baseball, cycling, swimming recs pg 3 last P)<br><br>Key factors to evaluate youth athletes with suspected overuse injury are training volume and level of participation—also consider participation outside of formal competition (practice, training, etc). Repetitive load is considered a risk factor for many overuse injuries.<br><br>Types of injuries common:<br>-stress fx (risk factors: Overuse, decreased caloric intake, and overtraining)<br>-epiphyseal injuries<br>-apophyseal injuries<br>-FAI (in some cases like hockey)<br><br>Recommendations: Primary treatments include a period of complete rest of the injured area, physical therapy, an evaluation of mechanics, and a reduction in participation, with particular attention to | Some studies suggest that early specialization is helpful in highly technical sports. Animal studies have shown that the strength of epiphyseal cartilage to oppose tibial load decreases during puberty. A case control study of 1206 seven- to eighteen-year-olds demonstrated that over the course of 3 years, picking a main sport to focus on was an independent risk factor for injury even after adjustment for age and hours per week in total sports activity. Evidence that early single sport specialization has a negative effect psychologically (eg, documented burnout rates) is more abundant in research. Hall et al evaluated a large cohort (N = 546) of female basketball, soccer, and volleyball players in middle school and high school and compared anterior knee pain between athletes who specialized in a single sport and those who played multiple sports. The authors found that there was a small but significant increase in patellofemoral pain (1.5 x more likely) in those athletes who specialized in a single sport. Further research is needed to determine other injury patterns in youth athletes and their long-term consequences. It is also important to identify at which age range sport specialization is clearly detrimental and when sport specialization becomes beneficial to the elite athlete. Biomechanical studies are necessary to determine the risk of improper form on soft tissue or bony overload in a specific sport. |

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| | | | | | | following established guidelines for participation when they are available. Find the cause of injury, don't just treat the symptoms—ensure it doesn't become a chronic concern. | educate parents, coaches, trainers, and physicians on the risks of early sport specialization and the early signs of injury to prevent more serious injuries that would limit the participation of competitive athletes. |
| 6. | Sports-related injuries in youth athletes: is overscheduling a risk factor? | Luke, A (2011) | Survey | | **Population:** The study population included a sample of patients visiting 1 of 6 university-based sports medicine clinics in the United States and Canada for evaluation of a new sports- related or other physical activity–related injury. Patients between 6 and 18 years old were offered the survey. Signed informed parental consent and assent for children were obtained. Patients who presented with an injury unrelated to sports or physical activity were excluded. **Survey Tool:** Factors associated with ''overscheduling'' in youth sports | Overall, 360 questionnaires were completed (84% response rate). Overuse not fatigue-related injuries were encountered most often (44.7%), compared with AI (41.9%) and OFI (9.7%). Number of practices within 48 hours before injury was higher (1.7 +/- 1.5) for athletes with OI versus those with AI (1.3 +/- 1.4). Athlete or parent perception of excessive play/training without adequate rest in the days before the injury was related to overuse and fatigue-related injuries. Fatigue-related injuries were related to sleeping # 6 hours the night before the injury.<br><br>Until there are more definitive studies regarding fatigue, recovery time, and | Sports-related injury is the leading cause of injury among school-aged children. Overuse injuries occur as a result of repetitive microtrauma from chronic submaximal loading of tendons, muscles, or bones beyond the level required for fitness and conditioning gains, without adequate rest for positive adaptation—present w/ hx of increasing activity or repetitive movements. A major challenge in identifying relevant variables for overscheduling is defining criteria that would apply to different sports. Identifying modifiable factors related to overscheduling injury risk should provide direction for developing more appropriate, evidence-based, and safe scheduling recommendations for youth sports governing bodies and event administrators.<br><br>Overuse injuries were more prevalent than acute injuries (54.4% vs 45.6%). Fatigue was an apparent contributing factor in 13.3% of participants. Most common injuries involved the knee (85), followed by foot (29), spine (29), lower leg (26), shoulder (25), hip (19), and ankle (16). Tissue injuries comprised |

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| | | | | | were based on the literature review and expert consensus. The questionnaire was developed with input from sports medicine experts participating in an American College of Sports Medicine Roundtable on Youth Sports Scheduling in 2008. Keywords searched in the PubMed database (www.pub med.gov) included pediatric , overuse injuries , overtraining , scheduling , and sports injuries . The institutional review board at each participating institution approved the study. **Survey Protocol:** On arrival to the clinic, the parent and athlete were asked to complete the survey before meeting the physician (Figure 1). After the clinic visit, the subject's questionnaire was included or excluded, based on the physician's | injury risk in youth sports, we recommend at least 2 hours of recovery between moderate-intensity and vigorous-intensity sport-related training sessions and com-petitions that last more than 1 hour, to allow sufficient rest and nutrient recovery, and even more time to recover between consecutive games or practices.<br><br>We propose that an overscheduling injury be defined as an injury related to excessive planned physical activity without adequate time for rest and recovery | 274 diagnoses: ligament injuries/-sprains (45), tendinopathy (including strains and tendinitis) (40), apophysitis (25), cartilage problems (osteochondral or meniscus problems) (13), patellofemoral problems (subluxation or patello-femoral pain) (26), fractures (25), bone overuse injuries including stress fractures (24), soft tissue injuries (25), muscle strains (17), and spine-related problems (23). The injury sample included 33 concussions (9.2% of reported injuries). Contact sports, such as football and basketball, reported higher acute injuries, and running, basketball, and gymnastics indicated the most overuse injuries. Soccer, running, and baseball had the most OFI. Significant contributing factors for overuse injuries (Table 3) included the following: training error, overuse mechanism/ pathology, fatigue as a factor in the injury, and genetic predisposition. Acute injuries were primarily due to contact. Significant factors linked with fatigue-related injuries included training error, incomplete rehabilitation of a previous injury, overuse mechanism/pathology, fatigue as a factor in the, and genetic predisposition. Average amount of physical activity on the day preceding the injury was 2.0 +/- 2.1 hours (Table 4; all injuries combined), and during the 72 hours before the injury was 5.2 +/- 4.1 hours (median value, 4.5 hours). =0.071).Playing on more than 1 team or more than 1 sport at the time of injury was not significantly related to any injury |

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| | | | | | interpretation of whether the injury was related to sports or other physical activity. The physician then completed his/her portion of the survey (Figure 2), indicating the diagnosis and categorizing the injury into 1 of the 4 categories: acute not fatigue-related injury (AI), overuse not fatigue-related injury (OI), acute fatigue-related injury (AFI), and overuse fatigue-related injury (OFI). Responses were based on the clinician's interpretation of the history, physical examination, and any other clinical evaluations available on the initial visit only. All participating physicians in this study had pediatric sports medicine fellowship training. | | category. Athlete or parent perception of too much play or training over the immediate few days before the injury without enough time to rest between bouts was positively related to overuse injuries and fatigue-related injuries. Sleeping 6 or fewer hours the night before the injury was associated with all the fatigue-related injuries. However, no statistically significant association was identified between fatigue-related or overuse-related injuries and getting less sleep than usual or several days of decreased sleep. This study suggests that a positive association exists between overscheduling and injuries determined to be overuse related. Moreover, the high prevalence of overuse injuries (54.4%) observed here among the surveyed university-based sports medicine clinics underscores the validity of concern over this growing problem in youth sports. The amount of time needed for children and adolescents to sufficiently recover between bouts of sport-related physical activity (training sessions or competitions) is likely multifactorial, considering physical activity intensity and duration, environmental conditions, nutritional challenges (eg, carbohydrate, water, and electrolyte recovery), and psychosocial factors— to minimize acute overload and undue fatigue, an appropriate schedule that allows for adequate recovery between games or practices should be strongly considered. |

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| 7. | Psychosocial Risk Factors for Overuse Injuries in Competitive Athletes: A Mixed-Studies Systematic Review | Tranaeus, U (2021) | Systematic Review | Low-Moderate | Medline (Ovid), Web of Science Core Collection and PsycINFO (Ovid) were searched from inception to July 2021. Hand searching of journals and reference checking were also performed by the authors. The following keywords were used together with other related words, and with appropriate truncations and Boolean combinations of words and operators: "overuse injury" AND "sport" AND "psychology" AND "risk factor" limited to academic peer-reviewed journals in Swedish, English, German, Spanish and French. A complete search was performed by librarians at Karolinska Institute, Sweden after several test searches. See Appendix 3 of the ESM for a full documentation. Studies reporting | Nine quantitative and five qualitative studies evaluating 1061 athletes and 27 psychosocial factors were included for review. Intra-personal factors, inter-personal factors and sociocultural factors were found to be related to the risk of overuse injury when synthesized and reported according to a narrative synthesis approach. Importantly, these psychosocial factors, and the potential mechanisms describing how they might contribute to overuse injury development, appeared to be different compared with those already known for traumatic injuries. There is preliminary evidence that overuse injuries are likely to partially result from complex interactions between psychosocial factors. Coaches and supporting staff are encouraged to acknowledge the similarities and differences between | Overuse injuries develop most often because of repetitive loading of the musculoskeletal system without adequate rest that allows the structures to adapt to the training load and may occur suddenly without identified events.<br>**Intra-personal Factors:**<br>The combination of competitive motivation, goal-oriented motivation and exercise dependency increased the risk for overuse injuries. Athletes categorized in the group with the highest risk for overuse injuries were characterized by a higher level of athletic identity in comparison to athletes in the other two groups, who reported fewer overuse injuries. a decrease in perceived personal accomplishment in sport over 3 weeks of training increased the risk of sustaining an overuse injury during the following period. One study showed that perceived negative life event stress was the main variable allowing discrimination between athletes in a psychosocial risk profile for overuse injuries (who presented with elevated stress values). Athletes in a psychosocial risk profile for overuse injuries were characterized by higher values for perfectionistic concerns than athletes in the other profiles, whereas perfectionistic strivings did not contribute to discriminating at-risk athletes for overuse injury.<br>Excessive training as well as training despite being mentally and/or physically tired, were described as behaviors increasing the risk for overuse injuries. |

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| | | | | | psychological or psychosocial risk fac-tors for overuse injuries in athletes published in academic peer-reviewed journals in the above-mentioned languages until July 2021 were eligible for quality assessment. Eligible studies had to include competitive athletes as a population. Studies where the outcome was not clearly stated, or where overuse injuries were pooled with other injuries (e.g. traumatic or chronic injuries), were excluded. Published papers without empirical data, not presenting results about overuse injuries or not assessing psychosocial factors, were excluded as well as duplicates. Articles assessing psychosocial factors as an outcome after overuse injury were also excluded. | traumatic and overuse injury aetiology.<br><br>A meta-synthesis table summarizing the findings of both quantitative and qualitative studies and providing an overview of the certainty of evidence for each factor is presented in Table 4.<br><br>Based on the results from these studies, we suggest that a number of intra-personal, inter-personal and sociocultural factors might influence the risk of overuse injuries and should, therefore, be considered in sports burdened by overuse injuries.<br><br>Athletes exposed to psychosocial stress may be more susceptible to overuse injuries through the synergetic effects of psychosocial and physical stress. | A range of cognitive interpretations that followed the perception of the gradual overuse symptoms were described as psychosocial mechanisms resulting in more severe or prolonged overuse injury episodes—brushing off injuries to continue training prolonged injury effects. Athletes expressed that they ignored the bodily warning signals and neglected the possible negative long-term consequences of training despite these symptoms. In the late stages of overuse injuries, athletes were found to accept the pain and decreased function associated with the injury and to continue training and competing, unless the pain had increased to an intolerable level or if strong recommendations were received from medical professionals or coaches to adapt their training. Sport-specific stressors (e.g. insecure position in the team) and non-sport stressors (e.g. stress from work or school) were also reported as risk factors for overuse injuries. Putting too much pressure on oneself was a personal stressor identified as a risk factor in two qualitative studies. Having sustained previous injuries was also described by athletes as a risk factor for subsequent overuse injuries, in the sense that they were aware of what recognizing themselves as injured again would mean in terms of absence from training, low self-efficacy and negative emotions associated with the rehabilitation period.<br>**Inter-personal Factors:**<br>Athletes categorized into the psychosocial risk profile for overuse injuries reported having a relatively |

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| | | | | | | | poor relationship with their coach, in comparison with the other profiles. Athletes reporting their coach as a source of stress were found to be at greater risk of sustaining an overuse injury. In this study, none of the other inter-personal stressors investigated (teammates and friends) was associated with overuse injury risk.<br>The overall lack of social support from family, friends and teammates, as well as the specific lack of social support from coaches and medical staff when facing an overuse injury were also reported by these athletes.<br>**Sociocultural Factors:**<br>Pain normalization was described as the core feature of a 'culture of risk', which is associated with a low acceptance of complaining. These athletes were described as ensuring their cultural embodiment by showing their adherence to the social values of their club (e.g. sporting success, striving for perfection) through 'mentally tough' attitudes and behaviors. This meant accepting pain as an integral part of sport and continuing to train and compete despite experiencing pain, which ultimately resulted in overuse injuries.<br><br>The potential risk factors identified in our study (e.g. passion, athletic identity) suggest that the level of investment in the sport of athletes might be more important than their absolute level of performance in relation to overuse injuries. |

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| 8. | Developmental Training Model for the Sport Specialized Youth Athlete: A Dynamic Strategy for Individualizing Load-Response During Maturation. | Jayanthi, N (2021) | Nonsystematic review with critical appraisal of existing literature.<br><br>Level 4 Evidence | Moderate-high | Clinical review with critical appraisal of existing literature. | A number of factors must be considered when developing training programs for young athletes: (1) the effect of sport specialization on athlete development and injury, (2) biological maturation, (3) motor and coordination deficits in specialized youth athletes, and (4) workload progressions and response to load.<br><br>One of the earliest models of long-term athlete development recommended that youth progress from a competition-to-training ratio of 25:75 during early adolescence to a 50:50 ratio in late adolescence. Across a wide range of sports, youth competition injury incidence is consistently higher than injuries sustained during training. spending a high proportion of time in competition results in athletes' spending insufficient time preparing physical capacities during | Sport specialization has been associated with increased risk for overuse injury and burnout and with an estimated 60 million children participating in sports, it is now considered a public health issue. While many medical and sport organizations recommend against sport specialization prior to middle or late adolescence, the perception by young athletes and parents that specialization improves athletic performance and long-term athletic career prospects means that while risks of injury and burnout may exist, some are willing to specialize to increase their chances of success. Early sport specialization and focus on a single sport prior to adolescence has been advocated by some stakeholders in the youth sports industry to theoretically enhance athletic success, but with little data to support this claim. A recent systematic review demonstrated no superior benefit on task or career performance in populations of specialized athletes and multisport athletes.48 These findings have led multiple some experts to suggest that diverse, multisport participation may result in enhanced skill acquisition and limit the potential risks of injury. The International Olympic Committee generally discourages early sport specialization, it also acknowledges that "appropriate diversity and variability of athletic exposure within a single sport, while supporting sufficient learning of foundational skills and sport-specific technique and biomechanics to minimize injury risk and optimize performance, can be acceptable and |

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| | | | | | | training. These physical capacities are likely to be protective against injury and to ensure athletes are prepared for the demands of competition.<br><br>Although early specialization may pose a risk to some athletes, it is possible to have positive experiences and success with specialized training. When prescribing training load, practitioners should consider moderators of the workload-injury relationship (eg, age, training history, strength, aerobic fitness) and injury risk factors (eg, injury history, poor biomechanics, and biological maturity) that can affect load tolerance. Given the increased risk associated with high competition loads in youth athletes, training programs designed to develop physical qualities and neuromuscular control may offer a protective | healthy."-- there has been little guidance for athletes who specialize in a single sport at younger ages than recommended, leaving a large gap in evidence for minimizing injury risks and training young, specialized athletes.<br>High degree of specialization (choose 1 main sport, quit all other sports, and train/compete >8 months per year) has been associated with greater overall injury risk, specifically overuse, and serious overuse injury risk but not acute injury risk.<br>Lower risk injuries such as muscular injuries, apophysitis, and anterior knee pain syndromes may only require modification of workloads during rehabilitation, followed by staged progressions in training load.<br>When accompanied by movement diversity and variability of athletic exposure, participation in a single sport may result in positive health outcomes.<br>Certain individual athletes may carry more risk for overuse injury in the setting of sport specialization than others. Recommending that youth athletes avoid early specialization may be an oversimplification that ignores the importance of providing specialized youth athletes with training and competition guidance and monitoring through vulnerable periods.<br>A well-rounded training program that includes strength, conditioning, and sport-specific skills should be a priority.<br>Targeting physical qualities that are protective against injury (eg, muscular strength and aerobic fitness) and associated with improved performance, |

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| | | | | | | effect against injury while also enhancing performance. When considering the overall workloads of elite specialized athletes, coaches, and sports medicine practitioners should look for opportunities to develop physical qualities, flexible and adaptable movement strategies, and sport-specific skills, within a framework that prioritizes preparation (ie, training) over competition. | and interventions that are known to decrease injury risk (eg, integrated neuromuscular training). Participation in a secondary sport provides a break from the repetitive movements of their primary sport (eg, repetitive throwing, hitting, or jumping activities), may result in the development of more adaptable movement patterns, has been associated with superior perceptual expertise (decision making and ability to "read the play"), and may help protect against some factors associated with burnout.<br>Adolescent growth spurt is recognized as a stage of development when athletes are more susceptible to certain types of injury, specifically those injuries associated with the growth plate and overuse. During this phase of development, youth experience rapid gains in stature and then mass, predominantly as a result of increases in fat and fat-free mass (ie, muscle, skeleton, soft tissues, organs). The period of growth prior to and during the peak velocity height (PVH) is when an athlete may be most vulnerable to injury and when it is most important to modify training and competition loads.<br>Strategies can be employed to reduce the risk of overuse and acute injuries during the adolescent growth spurt, including the routine measurement of growth and maturation, the prediction and identification of the adolescent growth spurt, the monitoring of injury symptomology, and the prescription of developmentally appropriate training programs (load and content). Bio- |

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| | | | | | | | banded (ie, maturity matching) training intervention was employed to help academy players transition more effectively through the adolescent growth spurt and reduce injury risk. Players entering the growth spurt were assigned to a "conditioning program" that involved reductions in training load and activities that involved significant amounts of acceleration and deceleration. These changes were coupled with an increased emphasis on activities that developed and/or maintained coordination, balance, core strength, and mobility and involved the retraining of fundamental and sport-specific skills.<br>Neuromuscular deficits are primarily thought to be a major contributor to acute injury such as anterior cruciate ligament (ACL) tears. Coordination deficits have recently been identified in specialized, young female athletes. Risks of acute knee injuries such as ACL tears are reduced with proper neuromuscular training and to an even greater extent when applied in younger athletes. Neuromuscular training, targeting coordination deficits that increase injury risk, may ultimately prove useful for reducing the incidence of both acute and overuse injuries in young athletes.<br>A recent study examined relative hip and knee joint angular motion variability among adolescent female sport-specialized and multisport athletes to determine how sport specialization may affect motor coordination acquisition in young athletes. The sports |

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| | | | | | | | specialized group exhibited increased variability in hip flexion/ knee flexion coordination, knee flexion/knee abduction, and knee flexion/knee internal rotation while landing during a drop vertical jump task. The authors concluded that these altered coordination strategies involving the hip and knee joints, which may underpin unstable landings, inefficient force absorption strategies, and/or greater contact forces, can place the lower extremities at higher risk of injury in athletes who specialized earlier in their young careers. Sport-specialized athletes exhibited a smaller increase in peak knee extensor moment (desirable sagittal plane power) and a larger increase in peak knee abduction moment (injury risk–related frontal plane load) across visits compared with the multisport group. Thus, sport specialization before pubertal maturation may promote worsened biomechanics that can propagate through maturational development in young athletes.<br>More complex movements of the nonspecialized athletes, over time, would lead to a lower likelihood of overuse injury due to less homogenized muscle activation patterns, while the constrained movements in specialized athletes may increase chronic joint load and increase risk of overuse injury. Without opportunities to naturally experience a variety of load adaptive stimulus from sport diversification during maturation, youth athletes may not fully develop neuromuscular |

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| | | | | | | | patterns that may be protective against injury and potentially develop movement strategies that increase injury risk. Planned diverse motor skill opportunities and strength development during the growing years, combined with planned integrative neuromuscular training, may help optimize the potential for success in young athletes.<br>Stakeholders in youth sport to prioritize short-term performance achievements over long-term athlete development, meaning that some talented youth athletes are at risk of experiencing high training and competition loading, insufficient recovery, and a high competition-to-training ratio.<br>Adolescent athletes who slept fewer than 8 hours per night were 1.7 times more likely to sustain an injury than those who slept 8 or more hours per night.<br>Adolescent athletes do not need excessive training loads to elicit positive training adaptations. These findings, taken with those of others, suggest that prescribing moderate training loads with small fluctuations is best practice for most adolescent athletes.<br>*FIGURE 3* |
| 9. | Youth athlete development models: A narrative review. | Varghese, M (2021) | Narrative review.<br>Levels 4 and 5 evidence<br><br>Low-moderate | low | An electronic databases search, including PubMed, Google Scholar, ScienceDirect, National Institutes of Health, UpToDate, and Springer was conducted. Articles from 1993 to 2021 | A total of 110 publications (including peer-reviewed journal articles, governmental policies, and books) were identified by the search. Of these 110, 40 met the inclusion criteria and were reviewed. These | Structured training models are safe and feasible and may have added benefit to physical fitness and that there is no negative impact on cognitive or academic performance, growth, or body composition.<br>Physical activity during pre-adolescence should be fun and a part of everyday life for the child (eg, running around at the playground or at home). It is important |

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| | | | | | were included. The search terms long term athlete development, LTAD model, youth physical development, youth athlete development, sports specialization, and pediatric athlete, among others, were used.<br>We included articles on athlete development in the pediatric population. We also included all articles on the effects of athlete development models in the pediatric population. We excluded articles on athlete development in other populations such as adults greater than 23 years of age, focused on team building rather than individual athlete training, short-term training programs, and training programs unique to only 1 specialized sport (Figure 1). | included 31 peer-reviewed articles, 7 governmental policies, and 2 books. Additional articles on sports specialization, physical activity, and public policy were included for background information as needed.<br><br>Several models of youth athlete development are discussed in this article. More recent models have built on previous models to incorporate more age- and development-specific recommendations; however, no singular model could be identified as the gold standard for youth athlete development, especially given the lack of empirical data to support these models. | for the parent or other guardian to give access to unstructured play time.<br>The youth physical development (YPD) model stages are early childhood (ages 2-4 years), middle childhood (ages 5-9 years), adolescence (ages 10-19 years), and adulthood (ages 20-21 years). It also takes into account maturation status (pre-PHV and post-PHV), training adaptation (neural or neural + hormone phases), training structure (structured vs unstructured), and physical qualities of training (fundamental movement skills, sport-specific skills, mobility, agility, speed, power, strength, hypertrophy, endurance, and metabolic conditioning). YPD emphasizes that it is possible to train an athlete in any of these physical qualities at any stage throughout childhood and adolescence. However, the YPD model does recognize that there may be optimal times to train each physical quality. |
| 10. | Age of early specialization, competitive volume, injury, | Meisel, P (2021) | Cross-sectional study; | Low to moderate | An anonymous questionnaire was administered to a convenience sample | A total of 772 participants (145 girls, 627 boys) completed a survey. All participants | In the US, a number of issues affect the youth sport experience, including an emphasis on short-term competitive success, a culture of elite travel and club |

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| | and sleep habits in youth sport: A preliminary study of US youth basketball. | | convenience sample.<br><br>Level 4 evidence<br><br>Moderate | | of youth basketball players between 13 and 18 years of age from across the United States. Participants were queried about multiple factors, including the extent of their participation in organized basketball and other sports, time away from organized basketball, injury, sleep, and feelings of exhaustion related to basketball participation.<br><br>The purpose of this article is referred to as sport specialization (noting that in the NBA/USAB guidelines recommend delaying single sport specialization until the age of 14 years) and its potential relationship with several outcomes. | played for a select or elite club basketball team and/or a high school basketball team. Overall, 49% played more than 50 games within the past year. A total of 73% were specialized in basketball, 58% prior to age 14 years, and 35% prior to age 11 years. In all, 70% reported less than 1 month away from organized basketball within the past year, and 28% reported no time away. A total of 54% reported sleeping less than the recommended 8 hours each night during the school year. Within the prior year, 55% reported feeling physically exhausted and 45% reported feeling mentally exhausted from basketball. Regression analysis did not find any significant relationships between early specialization prior to age 14 years and basketball-related injury or feelings of mental or physical exhaustion. | teams, and exclusive camps and showcase events that may be perceived to be essential in achieving college scholarships and professional careers. These have contributed to a youth sports experience that fosters early sport specialization, high-intensity and year-round training, and frequent, organized competition.<br>Although the NBA and USAB recommend delaying specialization in basketball until at least age 14 years, the results indicated that 57% of the youth basketball players in this preliminary study specialized at younger ages, girls more so than boys. The NBA and USAB youth guidelines recommend a maximum of 7 months per year in organized basketball for players aged 12 to 14 years, and a maximum of 9 to 10 months per year in organized basketball for players in grades 9 through 12. Of interest, among the players we surveyed, no more than 12% met the NBA and USAB recommendations. 54% of players reported less than the recommended 8 to 10 hours of sleep per night during the school year. |

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| 11. | Systematic review of health organization guidelines following the AMSSM 2019 youth early sport specialization summit. | Herman, DC (2021) | Systematic Review | Moderate | Published articles pertaining to sport specialization were identified with a predetermined search strategy. Using the NCBI PubMed, Embase, Cochrane, CINAHL, and SPORTDiscus databases, peer-reviewed, English-language articles from January 1, 2000, to December 31, 2018, were identified using keywords (Appendix Table A1, available in the online version of this article). The search excluded animal-based studies and was not limited by age parameters. Articles in full-text form were included that reported on recommendations or interventions by health organizations or health representatives of sports organizations. Articles that did not provide recommendations or practice guidelines were excluded. | Recommendations across organizations were primarily clustered in the Physical Development/Load (43%), Facilities and Resources (48%), and Sport Specialization (55%) domains. In contrast, the Psychological Development/Approach domain had fewer recommendations (20%). The most common recommendations endorsed concepts: "Monitor athlete well-being," "Youth athletes need access to well-trained, quality coaches," "Multi-sport participation," "Limit early organized participation and/or training," and "Parents require awareness of training, coaching, and best practices." The level of evidence provided to support a given recommendation varied significantly. The level of detail and the consistency of terms used throughout the results were typically low. | Sport specialization is typically associated with high volumes of training and competition year-round, and these behaviors may place athletes during times of growth and development at increased risk for lower extremity injuries, particularly overuse injuries.<br>There is a need to monitor training loads that account for the maturation level of the athlete and the need to include injury prevention strategies.<br><br>The generalization of the current recommendations lack specificity and supporting evidence to apply across sports, reflecting our findings in lack of specificity of recommendations by health organization identified in this review. Similarly, there was a lack of specificity regarding who should be responsible for implementing the monitoring strategy, such as a coach, parent, or sports organization.<br><br>Recommendations supported the concept that adequate time should be provided for rest and recovery to minimize injury risk related to overuse and decrease burnout; however, there was a lack of specificity regarding best practices.-- One recommendation common to 3 health organization guidelines was that sport-specific participation should be limited to approximately 8 months or less per year with 2 to 3 successive months off.<br>The most commonly offered remedy was to provide education that allows coaches, parents, and athletes to adhere |

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| | | | | | The identified articles were reviewed independently by 2 authors, and disagreements were adjudicated by a third author. Titles and abstracts of all search results were screened for potential relevance. Any citation that was deemed potentially relevant was retrieved in full text and assessed in accordance with the above criteria. All included items were used to generate a summary of existing guidance on youth sport specialization. Data abstracted from the identified sources included type of study and recommendations. Recommendations were sorted into 15 defined categories based on common elements identified during the review process. For the purposes of organization and discussion, these 15 categories were | Recommendations were frequently made without reference to potential outcome measures or specific strategies that could be used for practical implementation in the community. | to training load and to monitor for the development of symptoms to suggest burnout.<br>Organizations' consensus was that early intensive training, seen during youth sport specialization, may contribute to negative health outcomes, including an increased risk of injury and sport dropout/burnout without necessarily providing a substantial benefit to future success for elite athletes. Furthermore, recommendations were to delay intensive, single-sport participation until approximately adolescence. Prior to this transition, sports training in the youth athlete should focus on the acquisition of fundamental sport-specific movements and techniques with a goal to improve overall neuromuscular development, strength, and conditioning.<br>The lack of specific guidance may be a barrier that inhibits the ability of physicians, coaches, parents, and athletes in the community to enact appropriate sports participation programs.—necessitates need for vigilance from parents and coaches to be on look-out for possible signs of psychological/physiological sports fatigue. |

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| | | | | | grouped into 4 thematic domains. | | |
| 12. | Sensitive periods to train general motor abilities in children and adolescents: do they exist? | Van Hooren, B (2020) | Critical Appraisal of Evidence<br><br>Level 5 Evidence | Low-moderate | A narrative synthesis rather than a systematic review approach was used as only few studies have investigated the effects of an intervention where groups of different (biological) ages performed training while using a control group to partition out the effects of training and maturation (34,41,49,55). A systematic review on this topic would therefore be premature. Furthermore, the aim of this study was to provide a critical appraisal of the rationale behind generic sensitive periods as proposed in athlete development models rather than providing a comprehensive overview of all studies on this topic to date. Nevertheless, the search process was performed as systematically as | See conclusions section.<br><br>These findings suggest that the most appropriate training modality during the hypothetical sensitive period may differ between individuals depending on the previous training experience and genetic predisposition.<br><br>These findings therefore question the validity of generic sensitive periods as proposed in many athlete development models and have important consequences for those involved (parents, coaches, etc.)—holistic approach to each athlete, must consider additional factors such as other teams, previous participation, frequency, intensity, etc. that the athlete is subjected to.-- train all physical attributes during all stages of development. | The evidence provided in the updated model (6,14) as well as other LTAD models that feature sensitive periods (65) is primarily based on the idea that an accelerated growth and maturation-related development of a physical attribute (e.g., weight lifted during squatting) or derived general motor ability (e.g., muscular strength) also leads to a greater sensitivity to training. LTAD models divide the physical aspects of sports into 5 general motor abilities: flexibility, speed, coordination (sometimes referred to as skills), endurance, and strength. Although this reductionism is helpful to reduce the complexity of sports to 5 manageable constructs, it (incorrectly) implies that there are distinct motor abilities that can be trained independently, and each have separate sensitive periods. Such simplification for example implies that maximum running velocity (speed) can be improved independently of coordination or strength. It further implies that the subsystems that mature and are involved in coordination are (largely) different than the subsystems involved in speed or strength, resulting in separate sensitive periods for these general motor abilities. The findings collectively suggest that there are no general motor abilities, but rather that each motor skill is a result of a complex integration of abilities that are partly task specific. It is suggested that children need to exercise at a higher |

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| | | | | | possible by searching electronic databases of Google Scholar and PubMed for relevant literature using combinations of keywords and Booleans that included (youth OR children OR adolescents OR pediatric OR young) AND (sensitive periods OR windows of opportunity OR training emphasize periods OR optimum periods OR periods of accelerated adaptation OR critical periods) AND (resistance OR strength OR weight OR sprint OR speed OR endurance OR stamina OR flexibility OR suppleness OR plyometric) AND (training OR intervention). No limits were applied to date of publication or article types. Hand searching for (to be published) articles in databases and reference lists and forward citation searching of included | some training methods should be emphasized at certain periods (e.g., prioritizing motor coordination training when motor coordination is impaired during PHV in an attempt to reduce injuries. | intensity (>85% of their maximum heart rate) and with shorter breaks to elicit the same adaptations as adolescents and adults.<br>Young athletes have been reported to be particularly susceptible to injuries before and during the growth spurt, and careful prescription of a training program (i.e., training mode and characteristics) is especially important during these periods to prevent injuries that may limit future potential. The complexities of training/match load management in the growing and maturing child to promote training adaptations and subsequent athletic performance, combined with the susceptibility to acute and chronic injuries, are often not taken into account in LTAD models that promote sensitive periods.<br>Prior experience will affect how certain neural circuits respond to future experience, suggesting that (lack of) prior training experience also determines whether sensitive periods exist—**prior exposure to complex movement patterns contribute to future success and gains in said patterns.**<br>A meta-analysis on strength and power training to improve measures of power, strength, and speed in youth athletes showed that adaptations were generally larger for untrained than for trained individuals—**large gains occur in early training due to untrained potential and growth factors.**<br>These findings indicate that each motor skill and derived general motor |

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| | | | | | studies was also used to identify additional relevant articles. | | ability can be trained by many different methods, and each training method is potentially most effective during differing stages of development. The effectiveness of a training method also depends on the characteristics of the training (and competition) such as the amount of resistance, sets, and repetitions, the duration of intervals and rest periods, and the total load of activities undertaken at school, other sports, and travel teams. |
| 13. | Misconceptions on Multisport Athletes | Huffstutter, N (2021) | Blog Anecdotal evidence<br><br>Level 5 Evidence | Low-moderate | Anecdotal blog post. | See conclusions. | Specialization sells because it's an easy sell—the promised outcome is something we want to believe. The existence of a direct path from deliberate hard work to a desired destination is the core of the American Dream. Actual compatibility with the sport isn't nearly as big of a factor until after puberty. **Early specialization athletes are often missing something in their movement literacy, and sport-specific skills are impossible to teach in the absence of the necessary physical ability to perform those skills. Kids have a pre-maturity window to maximize fluency in as many foundational movement patterns as possible, and multisport participation is an effective way to fill these buckets.** Being a multisport athlete in the modern youth sports landscape is a remarkable act of commitment. It requires feats of scheduling, transportation, and communication, as well as a budgeting of time, money, and physical energy. Though there isn't a right way to develop that 10-year-old, there is |

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| | | | | | | | definitely a wrong way—while all roads can lead to Rome, the scarcity of athletes and the number of kids who've quit sports by the age of 13 indicate that most don't get to where they're going. (And let's be clear, *Rome* is not the national team or the pros or D1; it's any goal-based destination: a high school team, a higher-level club team, or just improved performance on a current youth team.) |

## Early Sports Specialization/ Overuse Injuries

**Via Portney Table 36-1: Summary of Levels of Evidence (2020).

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## Injury Prevention/ S&C Principles

| | Article Title | Author/ Year | Level of Evidence** | Relevance to Capstone | Methods | Results | Conclusions |
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| 1. (14) | Anterior cruciate ligament injury prevention in the young athlete | Graziano, J (2013) | Clinical Report/ Review of current literature<br><br>Low-moderate | Moderate to high | Literature review of best evidence performed by author. | See conclusions.<br><br>Early adolescents may be ideal time to intervene in movement modification during sport-specific tasks to reduce future injury risk and better long-term outcomes.<br><br>Risk Factors:<br>-Physical fitness deficits<br>-Growth spurts<br>-Deficits in fundamental motor skills<br>-Adolescent Females (may be due to neuromuscular imbalances) | ESS leads to peak performance expectations at the time of greatest physiological change in youth athletes—this has increased prevalence of ACL injuries recently in youth sports, which were once a rarity. Late childhood critical for refining movement patterns. Frequency of ACL injury in young athletes has been increasing steadily around the ages of 10–12. Movement patterns play a critical role in ACL injury because they influence anterior tibial shear force, which directly strains the ACL. Early specialization, maturation, undeveloped physical skills, high-risk movement patterns, and an inadequate strength base all contribute to increased injury rates. Young athletes are vulnerable to injury secondary to growth-related factors such as growth spurts, maturity-associated |

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| | | | | | | Intervention Strategies:<br>-appropriate strength training (gradually increasing training loads that do not exceed physiological capabilities and improving flexibility, strength, and motor skills)<br>-active participation from coach to monitor and correct techniques for safety—feedback<br><br>**Children require more feedback when learning** a new task and acquire new motor skills more efficiently when tasks are separated into basic components. | variation, and immature or underdeveloped coordination and skills—which may be more prevalent with higher training frequencies and intensive training and competition seen today. Fatigue is related to poorer neuromuscular movement strategies and increased injury risk. During **growth spurts, core strength, neuromuscular ability, coordination, and proprioception become imbalanced**. Modifiable risk factors include muscle strength and coordination, dynamic hip and knee control, lower extremity joint stiffness, and force attenuation during landing. Lack of dynamic muscular control leads to increased valgus knee torque and increases strain on ligamentous tissues. Inadequate quad to hamstring co-contraction ratios may also contribute to these during sport-specific tasks. **Excessive trunk motion in frontal plane compounded with high GRFs and knee joint landing off the vertical axis increases knee joint vulnerability**. Inefficient movement patterns seen in pre-pubescent athletes include reduced knee flexion, knee valgus, excessive leg rotation, and decreased ability to attenuate GRFs at ground contact. To combat these-- foundational movement patterns, imposed |

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| | | | | | | | demands practice and experience. Weakness has been identified as a predictor of injury secondary to inability of the weak muscles to keep control forces in single-leg activities such as landing and cutting. Single limb training closely resembles sport-related tasks. Eccentric HS strengthening aides in resisting anterior and lateral tibial translation and tibial rotations. Unplanned/ unanticipated agility trains the HS in similar scenarios as unplanned cutting in sports. Anti-movement core exercises decrease trunk displacement variability from COG in landing/ cutting—add proprioception to re-train when athlete is off-center. Decreased flexibility during growth spurts (bone grows quicker than muscles)—focus on flexibility, balance, strength, and proprioception for pubescent athletes. |
| 2. (15) | An anterior cruciate ligament failure mechanism. | Chen, J (2019) | Controlled cadaver laboratory study | | One knee from each of 7 pairs of adult cadaveric knees were repetitively loaded under 4 times–body weight simulated pivot landings known to strain the ACL submaximally while the contralateral, unloaded knee was used as a comparison. The chemical and structural changes associated with this repetitive loading were | AFM–infrared spectroscopy and collagen hybridizing peptide binding indicate that the characteristic molecular damage was an unraveling of the collagen molecular triple helix. AFM detected disruption of collagen fibrils in the forms of | Nearly three-quarters of anterior cruciate ligament (ACL) injuries occur as ‘‘noncontact’’ failures from routine athletic maneuvers. Mechanism of noncontact ACL injury include aggressive quadriceps loading, excessive joint compressive loading, awkward landing or decelerating maneuvers, neuromuscular control deficit, and the induction of macroscopic tissue damage from repetitive submaximal ligament loading after |

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| | | | | | characterized at the ACL femoral enthesis at multiple hierarchical collagen levels by employing atomic force microscopy (AFM), AFM–infrared spectroscopy, molecular targeting with a fluorescently labeled collagen hybridizing peptide, and second harmonic imaging microscopy. Explants from ACL femoral entheses from the injured knee of 5 patients with noncontact ACL failure were also characterized via similar methods. | reduced topographical surface thickness and the induction of ~30- to 100-nm voids in the collagen fibril matrix for mechanically tested samples. Second harmonic imaging microscopy detected the induction of ~10- to 100 micro m regions where the noncentrosymmetric structure of collagen had been disrupted. These mechanically induced changes, ranging from molecular to microscale disruption of normal collagen structure, represent a previously unreported aspect of tissue fatigue damage in noncontact ACL failure. Confirmatory evidence came from the explants of 5 patients undergoing ACL reconstruction, which exhibited the same pattern of molecular, nanoscale, and microscale structural damage detected in the mechanically tested cadaveric samples. | simulated strenuous jump landings. Disruption of the collagen helical assembly results in reduced tensile strength and abnormal development of the collagen fibrils. It has previously been demonstrated in vitro that the ACL can experience fatigue failure in < 100 repeated jump landings when internal femoral rotation is limited. This similarity in collagen backbone disruption suggests that the ACLs from the patients may also have been subjected to severe repetitive loading cycles—repetitive loading in malproductive patterns. This study shows evidence of hierarchical multiscale damage at the ACL femoral enthesis induced by strenuous repetitive impulsive knee loading known to place the ACL under significant strain in vitro. The same indicators of multiscalar material fatigue damage were seen at the femoral enthesis of patients who had an ACL injury. Insufficient collagen remodeling and physiological repair time to restore homeostasis before next loading cycle hypothesized at ACL femoral enthesis. ACL multiscalar damage can result from submaximal mechanical loading and that damage can accumulate under realistic repetitive loading to eventually become a risk factor for ACL injury. Submaximal repetitive loading of the ACL |

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| | | | | | | These results suggest that the multiscalar, hierarchical structural changes observed at the femoral ACL enthesis are at least in part responsible for the reduction in structural integrity leading to noncontact ACL failure as a result of strenuous repetitive impulsive athletic maneuvers. These findings suggest that at least some ACL injuries may be attributable to an overuse injury caused by damage that accumulates in the absence of the time needed for repair. | means knee loading that did not generate force to failure in the ACL. Strenuous sports activities may place large loads on the knee in stopping, turning, cutting, and landing, but only a subset of those will place larger-than-normal loads on the ACL: specifically, those that include substantial internal tibial torques while landing a jump or cutting. Strenuous athletic activity in itself does not necessarily place unusual loads on the ACL and therefore would not necessarily cause a concerning increase in multiscalar fatigue damage at the femoral enthesis. |
| 3. (16) | Preventive effect of tailored exercises on patellar tendinopathy in elite youth athletes: A cohort study. | Bittencourt, NFN (2022) | Prospective crossover Cohort Study | Moderate-high | *Study design* A prospective crossover cohort design was implemented for elite youth male basketball and female and male volleyball teams. This cohort study consisted of 2 phases: a 1-year (2016) Observation period and a 1-year (2017) intervention period. The design of this cohort study (comparison between one year of observation and one year of intervention) were | The exercise prevention program significantly reduced the number of cases of patellar tendinopathy (PT), with athletes submitted to the intervention showing 51% less risk of developing PT. The overall PT incidence in the Observation year (5.9 per 1,000h of exposure) was | Patellar tendinopathy is an overload injury characterized by persistent patellar tendon pain and loss of function related to mechanical loading of the knee joint. Leads to a reduction in the ability to jump, land and/or change direction, which compromises athlete's sports performance and participation. The incidence of patellar tendinopathy has also been shown to be high (11.4 per 100 athletes per season, especially in youth elite athletes. Risk factors and/or factors associated with |

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| | | | | | based on the methods of a previous study that investigated the effects of preventive interventions for Achilles and patellar tendinopathy in elite athletes.<br>*Participants*<br>Elite youth male basketball and female and male volleyball athletes were recruited to participate in this study. Inclusion criteria were: youth male and female athletes who regularly participated in volleyball or basketball training sessions (3-5 per week) in a first-division sport club and who were engaged in regional and national competitions in a 2-season period. Athletes were excluded from the study if they left their team during the study period, since the research team would have been unable to monitor injury incidence of former athletes.<br>Participants and their legal representatives signed a consent form, and this study was approved by the University's Ethics in Research Committee (report number 56671416.2.0000.5108).<br>Two hundred and seventy-nine athletes were followed | significantly higher than that in the intervention year (2.8 per 1,000h of exposure) (P = .037). Twenty-six athletes developed PT in the observation year, whereas 13 athletes developed PT in the intervention year.<br>The authors speculate that men may be at a higher risk of developing patellar tendinopathy due to reasons such as higher body mass, larger muscle mass, and an ability to jump higher, resulting in greater tendon load. | patellar tendinopathy in recent investigations include deficits in ankle dorsi flexion range of motion, hip extensors strength, hip abductors and external rotators strength, a stiff landing, among others. These factors may be exacerbated and accentuated by increases in training load, in a web of determinants, contributing to the development of patellar tendinopathy in jumping athletes. Tailored intervention, specific to each athlete's assessment findings, is a more appropriate prevention approach.<br>Findings showed that a preventive program, tailored to each athlete according to the findings of a preseason clinical assessment, was able to significantly reduce the incidence of patellar tendinopathy, especially in youth male volleyball athletes. A progressive balance and coordination training intervention was implemented in addition to the regular soccer training activities of the premier league of female soccer players. Corroborating with our results, the authors found a 50% reduction in patellar tendinopathy with the intervention. The authors speculated that a balance training intervention might be beneficial to improve the proprioceptive capacity of ligaments and tendons. Sensory input might be higher in proprioceptive-trained individuals, and this might enhance muscle- |

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| | | | | | in the Observation period (first year of the study) and 277 athletes were followed in the intervention period (second year of the study). In the first year, players were tracked, and injury incidence was registered. In the second year, players continued to be tracked and an intervention composed of tailored exercises was applied according to the findings of a thorough preseason clinical assessment of each athlete.<br>*Exposure-hours and patellar tendinopathy diagnosis*<br>Questionnaires were completed by the team coaches to register the total number of exposure hours of each athlete. Exposure was defined as sports training or competition in which an athlete is at risk of sustaining an athletic injury. Athletes were encouraged to seek attention of a health professional of the team if they felt any pain or discomfort in the knee joint during the duration of the study. A physician with 15 years of experience in sport medicine, performed a thorough clinical examination of all athletes | | tendon unit function and integration, which could contribute to injury prevention. In this study, the intervention addressed risk factors for patellar tendinopathy assessed during preseason (ie, dorsiflexion range of motion restriction), aiming to increase the contribution of the other lower limb joints for force dissipation, so that the energy could be more evenly distributed through the entire kinetic chain.<br>Hip extensor weakness probably increases the demand on the knee extensors to dissipate the ground reaction forces during jump landings, which could contribute to the development of patellar tendinopathy. Athletes with patellar tendon disorders have been shown to have abnormal jump landing mechanics in comparison to healthy athletes, the intervention of the present study also included a jump landing strategy training, with the athletes being encouraged to land softly, by increasing trunk and hip flexion. Athletes with patellar tendinopathy have smaller range of motion in their lower limb joints after foot contact during landing when compared with asymptomatic controls. This abnormal landing pattern requires energy to be dissipated more rapidly, which leads to higher ground reaction forces and increased knee joint loading, |

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| | | | | | with musculoskeletal complaints. The diagnosis of PT was based on a detailed history and clinical examination. To be diagnosed with PT, participants had to: 1) have tendon pain on jumping/landing; 2) have localized tendon pain, confirmed by palpation of the inferior pole of the patella/patellar tendon/tendon distal insertion and; 3) have pain reproduced with tendon loading tests, such as the single-leg decline squat. The occurrence of patellar tendinopathy was defined as localized tendon pain associated with volleyball or basketball practice that caused the athlete to seek medical attention, irrespective of time loss. *Observation year* During the Observation year (2016), the number of patellar tendinopathy diagnoses and exposure hours were recorded by the team sports physical therapist. During the observation year, which served as the control period, the players were submitted to their usual basketball and volleyball warm-up and training | | potentially contributing to the development of patellar tendinopathy. Small increases in trunk flexion have been shown to reduce patellar tendon loads during jump landings. Increasing trunk/hip flexion during jump landings decreases the demand on the knee extensors to deal with the landing forces, thus decreasing peak patellar tendon force. Restricted ankle dorsi flexion range of motion is associated with decreased hip and knee flexion excursions and increased ground reaction forces during jump landings, which may increase the risk for injuries in athletes. |

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| | | | | | programs. *Intervention year* A tailored preventive program was implemented in 2017 (intervention year). The exercises were based on the results of the 2017 preseason assessment of each individual athlete which involved clinician-friendly tests, namely the weight-bearing lunge test; the hamstring bridge test, passive hip internal rotation range of motion. The tests of the preseason assessment were based on previously identified risk factors and factors associated with patellar tendinopathy in athletes, such as dorsi flexion range of motion restriction and hip muscles weakness. After the evaluation, the team sports physical therapist and the coaches discussed the needs of each athlete and of the groups as a whole and decided about the set of exercises which better addressed the needs of each athlete, considering their basketball or volleyball context. The multimodal exercise program included warm-up drills (basketball and volleyball specific), ankle stretches and self- | | |

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| | | | | | mobilization to improve dorsi flexion range of motion, hip and trunk strengthening exercises (i.e., hip bridge, squats, lateral and frontal planks), single-leg balance exercises, trunk mobility exercises, and movement training to improve landing pattern (soft landing, with greater trunk flexion). An example of the intervention used with one of the athletes in presented in Fig. 1. Each session lasted approximately 15-20 min and was performed 2 times per week during the warm-up throughout the season (10 months). The team's sports physical therapists were at the site during each preventive training session and their roles were to (1) provide specific instructions to the athletes, (2) provide verbal feedback to actively encourage athletes to perform each exercise with proper form (e.g., trunk position, knee alignment, soft landing). For example, during the warm-up drills, athletes used a ball to simulate basketball rebounding motions landing softly. In the weight-bearing tasks and jump exercises, the | | |

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| | | | | | athletes were instructed to keep the knee over the toes in order to maintain neutral frontal plane knee alignment and to land as softly as possible. | | |
| 4. (17) | Prediction of the Risk Factors of Knee Injury During Drop-Jump Landing with Core-related Measurements in Amateur Basketball Players. | Guo, L (2021) | Cohort study<br><br>Level 2-B evidence | High | Eighteen college-aged male amateur basketball players participated in the project. Kinetic and kinematic data for drop-jump (DJ) tasks were collected with force plates and infrared cameras. Raw data were processed to calculate knee joint angles and joint moments during DJ landing. Different components of core stability were represented by the sit-ups in 20 s (SU), trunk extensor endurance, trunk flexion and extension range of motion, dominant extremity single-leg stance time (DLS), and dominant extremity single leg hop distance, respectively. Correlation and regression were used to determine the relationship between jumping-related biomechanical parameters and core stability components. | SU shared significant variance with the peak moment of knee extension (PMKE, $p < 0.05$), the peak moment of knee abduction (PMKA, $p < 0.05$), and the angle of knee internal rotation at initial contact (AKRI, $p < 0.05$). DLS shared significant variance with the angular motion of knee internal rotation (AMKR, $p < 0.05$) and the AKRI, $p < 0.01$). SU and DLS together could explain 52% of the variance observed in the AKRI, and the result was significant. | On average, a basketball player performs 70 jumps in a game, and volleyball players jump approximately 60 times during 1 h of gameplay. The high and sudden ground reaction forces produced by landings translate into large external torques at the knee that can easily lead to soft tissues injury, especially for ACL injury. knee abduction angles and moments are the primary predictors of ACL injury risk. Increased abduction angles and moments on the knee can increase anterior tibial translation and loads on the ACL several-fold and lead to injury. **Inadequate core strength may compromise the dynamic stability of the knee and result in an increased abduction moment**, which may increase the strain on knee ligaments. core training could significantly **reduce the trunk flexion angle and the maximum knee internal rotation angle of young volleyball players during drop-jump (DJ) landing**. Correct knee positioning due to stronger core stability could reduce the overturning and rotating torque of the knee when landing and effectively reduce the risk of knee |

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| | | | | | | | injury. In addition to core strength and endurance, flexibility, motor control, and functionality should also be examined to evaluate core stability comprehensively (aim of study). TABLE 1.<br>Peak knee abduction moment during landing predicts ACL injury risk with 78% sensitivity and 73% specificity. Individuals who sustained an ACL injury displayed peak knee abduction moments during landing that were 2.5 times greater on average than the corresponding values in uninjured.<br>A stable core could reduce the overturning and rotating torque on the lower-extremity joints when landing and effectively alleviate the relevant joints loading.<br>The results of this study highlight the important role of the core in buffering the ground impact force and alleviating knee loading. Core strength could make the trunk rigid as a cylinder, strong and stable, which helps keep the whole body stable and decrease the disturbing force on the knee during landing.<br>3-dimensional angles of the knee at initial contact and maximal displacement when landing are crucial factors affecting knee injuries, especially ACL injuries. subjects undertaking a DJ task with less knee flexion and greater knee internal rotation and knee abduction at initial contact and |

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| | | | | | | | maximal displacement were associated with a greater rate of knee injury in sports.<br>DLS with eyes closed represented core motor control in the present study and was highly dependent on proprioception, which is the ability to integrate sensory information to maintain awareness of the positions of the body's segments and joints--Individuals who have good proprioception could activate lower-extremity muscles earlier and promote the function of the lower-extremity muscles during landing. |
| 5. (18) | Injuries in Muscle-Tendon-Bone Units: A Systematic Review Considering the Role of Passive Tissue Fatigue. | Vila Pouca (2021) | Systematic Review<br><br>Level 3 Evidence | Moderate | PubMed, Web of Science, Scopus, and ProQuest were searched on July 24, 2019. Quality assessment was undertaken using ARRIVE, STROBE, and CARE (Animal Research: Reporting In Vivo Experiments, Strengthening the Reporting of Observational Studies in Epidemiology, and the Case Report Statement and Checklist, respectively). | Overall, 131 studies met the inclusion criteria, including 799 specimens and 2,823 patients who sustained 3,246 injuries. Laboratory studies showed a preponderance of failures at the MTJ, a viscoelastic behavior of muscle-tendon units, and damage accumulation at the MTJ with repetitive loading.<br>Observational studies showed that 35% of injuries occurred in the tendon mid-substance; 28%, at the MTJ; 18%, at the tendon-bone junction; 13%, within the | Junctions between dissimilar materials as being locations where mechanical stress concentrates, meaning that these junctions have to sustain higher stresses even when the muscle-tendon/aponeurosis-bone unit is uniformly loaded. When mechanical stress concentrates, it can reach values that lead to failure on a nanoscale. When the loading cycle is repeated, the damage can spread to the microscale and, under certain conditions, result in partial tears on the ultrastructural scale or even in a complete rupture on the macroscopic scale. Low-cycle fatigue failure is that the structure can fail under 2 or more tensile loading cycles, each less than the ultimate tensile strength that by itself would not cause failure. In other words, multiscale damage |

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| | | | | | | muscle belly and that 6% were tendon avulsions including a bone fragment. The biceps femoris was the most injured muscle (25%), followed by the supraspinatus (12%) and the Achilles tendon (9%). The most common symptoms were hematoma and/or swelling, tenderness, edema and muscle/ tendon retraction. The onset of injury was consistent with tissue fatigue at all injury sites except for tendon avulsions, where 63% of the injuries were caused by an evident trauma. | can accumulate in substructures to weaken the structure to the point that it fails upon the next submaximal loading cycle.<br>The primary site of injury was at the distal attachment for all injury sites. Overall, 74% of the injuries occurred at the distal location, and 26% occurred at the proximal location. This was especially marked for tendon injuries, 40% of which occurred at the distal attachment as opposed to 5% at the proximal attachment. These sports/exercise injuries (after those with known trauma were excluded) were the ones that we could comfortably include in this category since these activities typically involve repetitive loading. Material fatigue could be involved in the cause of injury at all sites, with the exception of tendon avulsions, where evident trauma was the primary cause of injury.<br>The biceps femoris was the most commonly injured musculotendinous unit, representing 25.1%of the injuries. Of those, 14.4%were in the MTJ, and 9.7%were in the muscle belly. The highest incidence of MTJ injuries was in the biceps femoris (14.4%); that of tendon midsubstance injuries was in the supraspinatus (11.4%); that of tendon-bone junction injuries was in the patellar tendon (5.0%); that |

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| | | | | | | | of muscle belly was once again in the biceps femoris (9.7%).<br>Regarding specific musculotendinous units, the biceps femoris showed a balanced distribution, with 9.7%at the distal location and 8.6%at the proximal location. However, injury of the other hamstring muscles occurred more frequently at proximal locations. In the quadriceps group, they occurred more frequently at proximal locations.<br>Small nondisruptive injuries caused by a single tensile loading cycle to 30%of failure force were evidenced by microdamage in the MTJ detectable histologically. For larger nondisruptive injuries, the mechanical properties were more severely affected. This implies that repeated activities are a risk factor for musculotendinous tears.<br>If the movement requires large enough muscle forces, a small number of loading cycles can suffice to disrupt the tissue in a way that partial or even complete failure may occur. 92% of MTJ injuries were instigated by a noncontact event and occurred in well-trained athletes. This information, with the fact that in laboratory studies the MTJ showed signs of disruption at submaximal loads, strongly suggests that material fatigue damage can play a role in MTJ injuries. Tendon-bone junction injuries, particularly insertional tendinopathies or |

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| | | | | | | | enthesopathies, have been associated with overuse injury, which, as was hypothesized, may be related to material fatigue.<br><br>Many factors are known to affect the stresses at myofascial junctions, including the relative lengths and widths of the muscle's proximal and distal MTJ; however, it seems that MTJ and muscle belly injuries might be more common in the lower extremities. Although the exact anatomic and physiological reason for the failure remains unknown, material fatigue was certainly involved because of the many preceding loading cycles that did not cause injury. Beyond a certain injury threshold, natural muscle repair can prove insufficient, leading to loss of contractile tissue, fatty degeneration, and fibrotic scar tissue. |
| 6. (19) | Where Do We Start 'Em? Beginning GPP with the 1x20 (Plus Crawls, Carries, and Drags) | Arroyo, P (2021) | Blog<br><br>Level 5 evidence (anecdotal) | Moderate | Anecdotal evidence. | See conclusions. | Start adolescent athletes with a blend of general physical preparation (GPP) that employs a progressive loading and movement system. The key to involvement is to make the general basics attractive enough so that our young ones embrace them. The crux of the program includes basic movement patterns for the upper and lower body paired with resisted crawling, carrying, and dragging patterns. Execution involves interspersing a crawl, carry, or sled drag in between sets |

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| | | | | | | | of your chosen 1×20 exercise. Each movement has a progression where young athletes earn the next level by hitting a target load for an assigned repetition range, which requires control of bodyweight before loading with external resistance. Utilization of cross-crawl pattern for the cognitive pattern processing. Intervals are every two minutes on the two minutes (complete 20 reps in 2 mins, rest remaining time)—allows for coaching, cuing for movement quality. As each athlete improves in movement progression, strength levels, and stamina, you can compress the interval to challenge them to EMOM—a challenge to the aerobic pathways given a set of 20 will last about 25-35 seconds. Total body strength and work capacity are covered in this program, while leaving room for technical work for sprinting, jumping, cutting, and landing--can increase the volume and repertoire of jumps, throws, and tumbling as the workouts become more time-efficient (EMOM). |
| 7. (20) | Why screen side-step cutting movement quality? Implementing the Cutting Movement Assessment Score – Science of Multi-Directional Speed | Dos'Santos, T (2022) | Level 5 Evidence<br><br>Clinical Review of evidence | Moderate | Literature Review | See conclusions. | ACL injuries occur when mechanical load exceeds the ultimate tensile strength of the ligament, or due to a "fatigue failure" mechanism which entails accumulated high magnitudes and repetitive cycles of knee joint mechanical loading which, without sufficient rest and recovery, can |

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| | | | | | | | lead to micro damage and subsequent ACL failure from mechanical loads which previously could be tolerated. Side-step cutting is a key mechanism associated with ACL injury inciting events in multidirectional sports. These actions have the propensity to generate potentially large and hazardous knee joint loads (i.e., moments / torques of knee flexion, rotation, abduction and translatory moments) during plant foot contact, typically at extended knee postures, which have the potential to increase ACL loading and strain. Reducing potentially hazardous knee joint loads is considered the most viable strategy to reduce ACL injury risk and other knee joint health related conditions. Heightened knee joint loads are amplified during side-step cutting, and other high impact tasks such as landing and deceleration, when **aberrant "high-risk" movement quality and neuromuscular control deficits are displayed, such as knee valgus, lateral trunk flexion, and extended knee postures etc. (often in combination).** Evaluating movement quality should be considered a pivotal component of any sports science and medicine screening protocol. With this information, practitioners can then devise and |

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| | | | | | | | implement individualized ACL injury mitigation programs to address the specific deficits highlighted through the movement quality screening, which could potentially be more effective than generalized injury mitigation training. FIGURE 3<br>The CMAS is a side-step cutting screening tool, which is a qualitative screening tool based on the technical determinants of peak knee abduction moments—which is a valid and reliable screening tool for evaluating side-step cutting movement quality. Sub-optimal and unsafe technique may still be displayed during trials with low CMASs; therefore, it is advised to focus on the CMAS criteria where athletes scored deficits for specific injury risk mitigation training.<br>Athletes with low CMAS scores should be progressed to more complex screening tasks such as unplanned/externally directed attention cuts. |
| 8. (21) | How the 1x20 Won This Skeptic Over | Hoover, M (2022) | Blog<br><br>Level 5 evidence<br><br>Anecdotal Evidence | Moderate | Anecdotal Evidence | See conclusions section.<br><br>*Beginning programing with core lifts such as back squat, bench press, power clean, etc. for multiple sets of 3-5 reps will no doubt build strength but may lead to* | Ensures athletes get the most out of each level of adaptation before moving on to the next level. Programming goal is to squeeze out every drop of training adaptation possible and then move forward. Moving slower will extend the developmental process and leave somewhere to go as the athlete gains more experience and training age—to extend the desired strength adaptations later in the |

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| | | | | | | *compensatory patterns that could eventually lead to maladaptive injury patterns. This also bypasses crucial development of stabilizers and smaller muscle groups that may eventually become the weak links if not developed. Complete programs build resiliency, which may help reduce modifiable risk factors for youth athlete injuries.* | athletes training life. Longer periods of time in lower intensity and less-advanced modes leaves the athlete with room to grow later in their development process. Sport coaches, parents, and administrators that have less of a background in evidence-based athletic development—or no background in it at all—often judge s&c performance based on absolute strength numbers. All layering or "block" systems are built on progressions, whether in movement, volume intensity, proficiency, etc.-- produces results with greater efficiency and safety. Basis of layering system is to develop the strength and full-body movement proficiency to be able to prepare our athletes for the heavier loads, increased volumes, and more-advanced training protocols that their training age and adaptation process demand. Programming used to modify/regress sport-specific skills athletes need to be successful in given sport and develop it slowly over long period of time. General progression of program is from Block 0 to Block 1 and then transition to Block 2. As advanced to Block 2, the program progresses to the use of a standard and dependable 5×5 program for those core lift movements with auxiliary movements working from 1×20 to 1×14, to 2×8, and eventually to 3×6. Progressions come from |

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| | | | | | | | bodyweight movements through multiple levels of movements and movement variations that have all been adapted based on transferability to sport-specific tasks. It provides the athlete with thousands of reps of developmental movements for every joint angle and muscle in a progressive manner in both movement proficiency and intensity. In this programming, athletes are exposed to the entire range of the force-velocity curve in each set. The lower load initially allows the athlete to move the first few reps with close to max velocity, particularly in the early parts of the program. As they progress through the set, they will hit reps for speed-strength, strength-speed, and eventually max strength, all in the same set but with 18-25 different movements. The assignment repetitions (20) are designed to be a range of reps above and below the target and are tied to a process that clearly lays out how and when the athlete should progress the load. This program uses the 1×20 protocol to build a deep base of total body strength and movement skill over a relatively long period, designed to reverse engineer sport skills and develop a road map that ensures there is no skipping of adaptive potential en route to the advanced programming (high school program) with core lifts. |

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| 9. (22) | Study protocol for a prospective cohort study identifying risk factors for sport injury in adolescent female football players | Tranaeus, U (2021) | Prospective Cohort Study<br><br>Level 2 Evidence | Low-moderate | The Karolinska football Injury Cohort (KIC) is an ongoing longitudinal study that will include approximately 400 female football academy players 12–19 years old in Sweden. A detailed questionnaire regarding demographics, health status, lifestyle, stress, socioeconomic factors, psychosocial factors and various football- related factors are completed at baseline and after 1 year. Clinical tests measuring strength, mobility, neuromuscular control of the lower extremity, trunk and neck are carried out at baseline. Players are followed prospectively with weekly emails regarding exposure to football and other physical activity, health issues (such as stress, recovery, etc), pain, performance and injuries via the Oslo Sports Trauma Research Center Overuse Injury Questionnaire (OSTRC- O). Players who report a substantial injury in the OSTRC-O, that is, not being able to participate in football | Ongoing prospective study. See conclusions.<br><br>The overall aim of the Karolinska football Injury Cohort study (KIC) is to identify risk factors for injuries in adolescent female football players from a bio- psychosocial perspective. Specific aims are to determine the incidence of injuries in young female football players and to identify modifiable risk factors for such injuries. Finally, our aims include to describe changes in muscle strength and range of motion (ROM) over a year, trajectories of pain and to identify important factors for not being injured over a year. | Studies show that common injuries in female football players are joint and ligament injuries to the knee and ankle joints as well as muscle and tendon injuries of the thigh. Female football players have more absence days from football due to injuries compared with male players. For players with a history of injury, the risk of osteoarthritis in lower extremity joints are high and greater than in the general population. Risk factors in this setting can be classified as biopsychosocial factors. Biological risk factors for injury in female players are previous injury, a hamstring/quadriceps ratio of less than 55%, increased body mass index, as well as results of plyometric tests, for example, poor performance in drop jump landing test is associated with increased risk of ankle injury. Other biological risk factors associated with an increased risk of injury during the season are young age, physical complaints at the beginning of the season, and lower level of preseason aerobic fitness. **Psychological risk factors reported includes somatic trait anxiety, mistrust, ineffective coping, life event stress and perceived mastery climate. Social factors that influenced the risk for injury in female athletes** |

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| | | | | | activities, or have reduced their training volume performance to a moderate or major degree, are contacted for full injury documentation. In addition to player data, academy coaches also complete a baseline questionnaire regarding coach experience and education. | | **are coaches' and player's education regarding injury prevention strategies, and stress from teammates and coaches.** |
| 10. (23) | Plyometrics and jump training, part 1: working back from the sport | Coyne, J (2022) | Expert Opinion with literature review Level 5 Evidence | Moderate | Anecdotal evidence with literature review performed. | See Conclusions section. | Prioritize sporting demands and positional demands within specific sport in programming over any individual deficiencies-- exception is when the individual deficiencies are extremely pertinent and need to be fixed before the athlete can compete in their sport. First factor to consider is what type of stance the athlete is in when he or she produces force or jumps. Another factor to consider is the contact/contraction time the sport allows for producing the force needed for the activity and comparing that with the contact/contraction time of the jumping exercises you are using. The lower on the force-velocity curve you get, the lower the contact/contraction times allowed to produce force in the activity. Most of plyometric training programming may be most advantageously trained just above, at or below where the activity you want to improve sits on the force-velocity curve. Primary choices to augment maximal velocity |

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| | | | | | | | sprinting performance may be jumps/plyometrics with contact times below ~200ms for bilateral jumps and ~300ms for unilateral jumps (e.g., bounds or pogo-type jumps). None of this implies to not do jumps with contraction times outside of these bandwidths to improve certain aspects of performance if diagnosed/warranted. You may, for example, want the athlete to improve their impulse through time on the ground or "feel" the ground to generate force. There is a fine art in balancing "relevant" plyometric activity with what an athlete does regularly in their sport, so you are not overloading a particular stimulus—pre-training vs in-season training. Direction of the plyometrics or jump is the next factor that should be considered in establishing how relevant it is to the athlete-- vertical, horizontal, lateral, and rotational. **If the sport isn't strictly sagittal and vertical plane movements, jump training shouldn't be either**. Even still, it is likely that the inclusion of **lateral and rotational jumps are beneficial for injury risk reduction in the more "linear" sports like track & field.**<br>The final stage of any approach in jumping normally involves three components: the penultimate step, the transition or "cut step," and the ultimate, block or take-off step. The "cut step" is called a cut |

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| | | | | | | | because of the recovery transition of the take-off leg ankle across the penultimate stance leg – it "cuts" the penultimate stance leg at the ankle or lower shin, ideally. Most jumps in sport rely on an approach (it is somewhat rare that athletes will jump out of stationary positions in a sport other than during starts). At a minimum, this would benefit the coordination/sequencing aspect of jump take-offs. **Training both linear and curvilinear approaches to account for how athletes will jump in competition.** Benefits seen with ump training on sand ("quasi-closed" surface) range from increases in foot function with low amplitude jumps to a skill acquisition/contrast effect when returning to the surface they normally compete on. Athletes can feel "pushing the ground away" much better on a track after jumping work in a long jump pit. |
| 11. (24) | Misconceptions on Plyometric Training | McInnes Watson, M (2022) | Expert Opinion/ Literature Review | Moderate | Literature review and anecdotal expert opinion | See conclusions section.<br><br>Pre-activation and anticipative skills may be quite different when we stick landings, as opposed to a full landing and takeoff—train both.<br><br>Effective joint stiffness and | **Extensive plyos have benefits for landing skill development and tissue resiliency from higher volumes**. Necessary to teach correct/safe landing, as high volumes of incorrect landing patterns can equally lead to issues down the road. The overuse of extensive methods can have its downfalls, and this is especially apparent when hoping that extensive movements will **prepare the musculotendinous** |

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| | | | | | | contribution of tendon elasticity carry over to modulate force at speed and result in faster GCT and potentially greater outputs. This all happens more effectively during a full sequence. | **systems for intensive landings and takeoffs.** In novice athletes, extensive variations will be critical to use early on for tissue adaptation, learning landing mechanical skills, and building proprioceptive awareness. Maximal/intensive plyometrics result in: higher GRF forces upon landing (spike in eccentric loading, loading capacity); increased joint stiffness and rate of modulating load at speed; faster coupling rate of the eccentric through to the concentric contraction; and heightened pre-activation of the working muscles prior to landing to facilitate the above which results in greater energy transfer.<br>When you introduce something new and intense, starting with extensive and supporting actions is useful in building capacities to deal with the new stimuli—then add intensive/ maximal effort plyos later. Treat plyometrics beyond being a small group of extensive movements and/or depth jumps and distinguish it as any locomotive movement with a landing and takeoff sequence, then it can be **treated in a similar way to sprinting (landing and takeoff sequence that has a GCT <0.25 seconds and GRFs that can exceed 5x body weight)**. Maximal plyometric training is specific to the individual and is also the stimulus that will improve |

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| | | | | | | | | neuromuscular parameters like decreasing GCT and increasing GRF and how their relationship interacts through elastic responses. A high emphasis should be placed on preparing for the unknown sensation of falling during depth/drop jumps; therefore, a higher emphasis can be placed on using more locomotive concepts as mentioned before that are self-regulating in nature, especially in young athletes.<br>Sprinting and plyometrics are complex skills, and the moment we break them down into separate distinctive phases, we step away from developing the skills acquisition relationship of them as a whole. These landing and takeoffs are blink-of-an-eye fast, so the carryover and transfer of starting with just eccentric loading, for example, has a diminishing return on investment—leads to smooth elastic coil and recoil actions for jumping.<br>Deeper ranges of eccentric loading capacity offer more force absorption, but **if goal is quick take off training should focus on stiffer and more efficient eccentric ranges (fine line between adequate force absorption and too much for power output).** The concentric phase is a recoil action—put simply, to achieve recoil, you require a coiling action. Without |

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| | | | | | | | the presence of the coiling action (eccentric loading phase), the concentric takeoff portion becomes largely muscle driven. |
| 12. (25) | Deceleration Training in Team Sports: Another Potential 'Vaccine' for Sports-Related Injury? | McBurnie, AJ (2021) | Critical Appraisal of Evidence and expert opinion<br><br>Level 5 Evidence | Moderate-high | Appraisal of best evidence; expert opinion. | See conclusions.<br><br>Team sport athletes need to be able to skillfully dissipate braking loads, develop mechanically robust musculoskeletal structures, and ensure frequent high-intensity horizontal deceleration exposure to accustom individuals to the potentially damaging nature of intense decelerations<br><br>*Multi-deceleration is achieved by: (1) maintaining a low COM and anterior placement of foot to shift the base of support relative to the COM to increase posterior braking impulse, (2) 'braking' earlier and over multiple foot contacts to distribute loads, and (3) visual scanning and situational awareness to improve* | High mechanical loading conditions observed when performing rapid horizontal decelerations can lead to tissue damage and neuromuscular fatigue, which may diminish coordinative proficiency and an individual's ability to skillfully dissipate braking loads. Furthermore, repetitive long-term deceleration loading cycles if not managed appropriately may propagate damage accumulation and offer an explanation for chronic aetiological consequences of the 'mechanical fatigue failure' phenomenon. The occurrence of near-to-maximal sprinting speeds (> 90% maximum sprinting speed; MSS) can be low during match play, and sprinting demands can vary between matches and positional roles. **In most team sports, deceleration is performed more frequently than near-maximum sprinting and intense acceleration movements during competitive matches.** Deceleration maneuvers may need to be carefully monitored and managed, due to their propensity to generate high-impact braking ground reaction forces, which may predispose lower-limb musculoskeletal structures to a |

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| | | | | | | *anticipation and increase preparatory times to facilitate the postural adjustments (points 1 and 2) and to moderate approach velocities.*<br><br>*Over the course of a long competitive season, in which elite performers may be required to perform in match play every 3 days (e.g., fixture congestion), an under-prepared athlete may find themselves in a vicious cycle of ever-increasing neuromuscular fatigue and tissue damage, with the accumulation of tissue microtrauma--it has been shown that the reduction of CK and associated detriments in neuromuscular performance may be possible when players have been accustomed to intense decelerations.* | heightened risk of neuro-muscular and mechanical fatigue. **Decelerations elicit higher mechanical demands (e.g., larger GRF peaks and loading rates), and thus, greater biomechanical loading than accelerations**. Team sport athletes may be exposed to an increased vulnerability of the muscle–tendon unit (MTU) properties in handling eccentric braking demands due to an increased necessity to perform more high-intensity accelerations and decelerations. Horizontal decelerations in team sports presents unique biomechanical (i.e., kinetic, kinematic and spatiotemporal) and physiological (i.e., metabolic, neural and MTU) characteristics. **The penultimate foot contact has been considered as a key 'braking step' for facilitating faster COD speed performance and alleviating potentially 'high-risk' knee joint loads-- players who ineffectively decelerate momentum prior to COD may experience increased knee joint mechanical loading during the final foot contact of COD**. High angular velocities of the lower-limbs joints are observed in the deceleration steps in which rapid triple flexion of the hip, knee and ankle joints are required for COM lowering and effective orientation of horizontal braking forces. |

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| | | | | | | | Particularly in distal muscle groups with long tendons (e.g., gastrocnemius-Achilles-soleus complex), these muscles may actually shorten to enable a compliant tendon to store, buffer and reduce the kinetic energy input to the muscle. In contrast, in the more proximal musculature (e.g., quadriceps), the role of active lengthening and recycling of energy by the muscles may be greater due to reduced tendon lengths. **Increased and rapid muscle activation during deceleration is critical for offsetting potential ligament loading of the knee during cutting tasks-- the combined functions of rapid pre-activation ability and mechanically robust tendons that act as 'series-elastic shock absorbers' play critical roles in regulating the high eccentric forces experienced within the musculoskeletal system during high-intensity decelerations and protecting against injury.** Deceleration actions have an increased risk for ACL injury due to their propensity to generate high multi-planar knee-joint loading (i.e., knee flexion, rotational and abduction moments) while the foot is planted, which may typically occur with externally directed attention (i.e., unanticipated COD maneuvers in sports. This may be due to the reduced time to make |

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| | | | | | | | preparatory whole-body postural adjustments, the increased knee-joint loading during unplanned actions may be disproportionately greater than the muscle activation required to offset the adoption of potentially high-risk frontal and transverse plane kinematics (e.g., increased lateral trunk flexion and inadequate COM position). The multi-step nature of these actions places preliminary deceleration as a crucial strategy for reducing momentum and subsequent knee-joint loading during the final foot contact of COD (Fig. 1) and can be considered a modifiable risk factor for ACL injury mitigation. Deceleration-related injuries may manifest from a long-term aetiology in which a **chronic imbalance between tissue degradation and remodeling may be pre-sent as a consequence of repetitive mechanical loads and an excess of eccentric muscle actions over longer periods of time in the absence of adequate recovery. The delayed recovery timelines of the passive musculoskeletal structures (i.e., tendons, joint structures and bones), which have been shown to undergo heightened mechanical demands during deceleration actions, may be indicative of a more chronic overloading, and hence structural failure manifesting in the form of chronic injuries (e.g.,** |

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| | | | | | | | **stress fractures and tendinitis).** In contrast, the acute ‘spikes’ in workload of high-speed running and their propensity to be associated with muscular-related injuries, such as hamstring strain injury, is potentially indicative of a more short-term consequence--this may be driven in part by neuromuscular fatigue.<br>By evaluating the performance of pre-planned decelerations over a range of distances (e.g., 5, 10, 15, and 20 m), a deceleration ‘gradient’ may be created and athletes may be identified who show poor performance in key metrics (e.g., peak/average deceleration and time/distance to stop)—reasonable to assume that identified athletes are likely to be underprepared for the physical demands of competitive team-sports, due to the even greater loading demands of performing unplanned decelerations in match play. |
| 13. (26) | Sensorimotor Contributions to ACL Injury | Avedesian, J (2022) | Expert opinion with literature review.<br><br>Level 5 Evidence | Moderate-high | Expert opinion with literature review performed. | See conclusions.<br><br>While all athletes can benefit from both styles of training, novice athletes or those in the early stages of injury rehabilitation should be initially placed in COD environments and then progressed | The rates of ACL injuries are steadily climbing in adolescents. **Sensorimotor performance defined as the integration between perceptual sensory input (e.g., vision, hearing, touch)** and biomechanical movement output (e.g., running, jumping, cutting, decelerating). Some of the key sensorimotor attributes to successful performance and staying injury-free may include: |

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| | | | | | | to agility environments.<br><br>*Proposed pathway to ACL injury:*<br>*1.Cascading events that begin with decreased visual-spatial attention, delayed reaction time/processing speed, and/or reduced working memory.*<br>*2.Perception-action mismatch between the athlete and surrounding environment (e.g., mistimed estimation of a defender's trajectory toward the athlete).*<br>*3.Delayed neuromuscular response (e.g., anticipatory quadriceps and hamstring response) that results in increased load on the knee joint during high-impact loading events.*<br>*4.Increased risk for ACL injury.* | 1.Working memory and pattern recognition – Remembering and recognizing the opposition's defensive scheme when in a certain position on the field.<br>2.Dual-tasking – Receiving the ball from their teammate while scanning the field.<br>3.Visual attention and multiple object tracking – Spatial recognition of the changing position of teammates and opponents.<br>4.Reaction time and processing speed – Avoiding oncoming defenders.<br>Any interaction an athlete makes with their environment is based upon three general concepts: the nature of the information, the complexity of the action to be performed, and the number of available response options.<br>Athletes who sustained an in-season, non-contact ACL injury performed worse on all measures of the assessments, including reaction time, processing speed, and working memory. **There is an association between worse visuo-motor reaction time and greater risk for non-contact lower extremity injury.**<br>Devices and software such as sensory boards, reactionary light devices, stroboscopic eyewear, and virtual/augmented reality* attempt to **target various sensorimotor performance** |

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| | | | | | | | **attributes: visual spatial-attention and reaction time, working memory, pattern recognition, and multiple object tracking.** Stroboscopic eyewear and sports-specific VR may be the most effective devices for training, while sensory board technology may be best for standardized assessments and monitoring change over time.<br>Agility is a rapid, whole-body movement in response to a stimulus, while COD is a rapid, whole-body movement that is pre-planned. **Agility attributes – Anticipation, visual-spatial attention, pattern recognition, visuo-motor processing speed, and reaction time.**<br>**COD attributes – Technique, linear/horizontal speed, neuromuscular asymmetry, and eccentric and deceleration control. Agility-based training is more random and chaotic (open-skill abilities), while COD training tends to be more controlled and pre-planned (closed-skill abilities). COD training is inherently stable, while agility situations present an unstable environment in which an athlete is under various demands/constraints from teammates and opponents, all while having to anticipate and make decisions under time and space constraints.** |

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| | | | | | | | In injury rehab, **high stress levels are associated with delayed reaction times, reduced attention capacity, and internal attentional focus**, all of which can be thought of as sensorimotor deficits. Previously mentioned technologies are fantastic tools for these exact purposes, especially early **in the rehab progression when athletes may not be able to get full "physical reps."** Transient deficits in cognition and oculomotor performance are hallmark signs of a concussive injury, but researchers are beginning to think that more subtle sensorimotor deficits may still linger even after athletes have been cleared to return to sport—sensorimotor training may be beneficial to mitigate future risk for lower extremity and ACL injuries post-concussion. |
| 14. (27) | Skeletal maturation and growth rates are related to bone and growth plate injuries in adolescent athletics. | Wik, EH (2020) | Cohort Study<br><br>Level 4 Evidence (weak study design) | Moderate | This study used growth, maturation, and injury data collected prospectively over four seasons at Aspire Academy, an elite sporting academy in the Middle East. The participants were male full-time student athletes, enrolled in the athletics program for the 2014/15 through the 2017/18 seasons. This study was part of a larger study on growth, maturation, and athletic development for which | Across the four academic seasons, 129 complete athlete seasons from 85 unique athletes were considered eligible for inclusion (Figure 1). For the analyses of growth rates, 86 athlete-seasons from 60 athletes (1.3 ± 0.5 seasons per athlete; range 1-3) satisfied the inclusion criteria. Maturity status could be analyzed for 108 | Confusion among coaches and parents on how to effectively and safely train growing children has been perceived as one of the important contributing factors to injuries in athletics. Rapid growth and the period around peak velocity height (PHV) have been associated with an increased risk of injuries in elite sporting populations, and suggested underlying mechanisms include decreased bone mineral density, increased tensile forces on vulnerable muscle attachments, |

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| | | | | | written informed consent was obtained from the athletes' guardians prior to data collection and ethics approval was granted from the Anti-Doping Lab Qatar Institutional Review Board (IRB Application #E20140000012).Only athletes who had not yet specialized toward a sin-gle event group were considered eligible for inclusion. These athletes followed a general athletics development program and typically participated in eight training sessions per week over the academic year from September to June, while following a comprehensive educational curriculum. Specialized athletes were not included for analysis in this study, as the majority had reached or were near skeletal maturity. Anthropometric screenings were conducted by ISAK (International Society for the Advancement of Kinanthropometry) Level 2 certified academy staff at the start and end of each season, which corresponded to the academic year. Measures were taken early in the morning prior to any | athlete-seasons from 71 athletes (1.4 ± 0.6; 1-3), where 64 athlete-seasons from 42 athletes (1.4 ± 0.6; 1-3) also satisfied the criteria for analysis of maturity tempo. Combined, the three samples included 117 different athlete-seasons from 74 athletes (1.4 ± 0.6; 1-3). Chronological age at the start of the season was 13.4 ± 1.0 years (11.7-17.2), with a stature of 163 ± 11 cm (137-184) and body mass of 53 ± 16 kg (28-112). Based on nationality, 91.5% of the athlete-seasons represented Western-Asian countries, while the remaining 8.5% represented Northern-African countries. A total of 87 time-loss injuries (0.7 ± 0.9; 0-3 per athlete season) were recorded for 18 287 AE, equating to an injury incidence of 4.8 injuries per 1000 AE. Over one season, 51.3% sustained at | decreased neuromuscular control, and reduced flexibility. Observational data from four seasons in a general athletics program revealed greater rates of bone and growth plate injuries in athletes with larger relative changes in stature and leg length over a season. Rapid growth in leg length was also associated with an increased overall risk of injuries. Almost half of the injuries in this study were bone injuries, with growth plate disturbances and avulsions being the most common injury type—where he incidence increased when athletes experienced larger changes in stature and leg length over a season. Monitoring changes in lower extremity segment lengths provides additional value when aiming to identify vulnerable athletes. More advanced maturity status, expressed as greater skeletal age and a higher attained percentage of predicted mature height, was associated with a lower rate of growth plate injuries with no differences in overall or bone injuries. This supports the observations of increased injury risk in later maturing athletes—watch for athletes experience PHV and growth changes… modify activity and volumes of activities.<br><br>**Focus on load management during critical phases, exposing young athletes to varying** |

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| | | | | | activities to minimize diurnal variations, following ISAK-recommended procedures,23 and were uploaded to a central academy anthropometry database. Stretch stature was measured using a wall-mounted stadiometer with a precision of 0.1 cm (Holtain Ltd.) and body mass using digital scales with a precision of 0.1 kg (ADE Electronic Column Scales). Body mass index (BMI) was calculated as body mass divided by squared height (kg/m2). Trunk height was measured using a stadiometer with the athlete seated on a purpose built table (Holtain Ltd.), and leg length was calculated as the difference between stature and trunk height. Skeletal maturation was assessed at the beginning of each academic year, using x-ray images of the athlete's left hand and wrist complex taken at the Radiology Department at Aspetar Orthopaedic and Sports Medicine Hospital. The images were interpreted and entered into an academy maturation database by the same | least one injury (32.5% with only one injury, 14.5% with two injuries and 4.3% with three injuries). The total number of days lost was 1254 (10.7 ± 24.7; 0-165 per athlete-season), corresponding to an injury burden of 68.6 days lost per 1000 AE. The majority of injuries were minor (65.5%; 3.1 per 1000 AE), fewer were moderate (17.2%; 0.8 per 1000 AE) or serious (17.2%; 0.8 per 1000 AE). **There were more injuries reported with a gradual onset (59.8%; 2.8 per 1000 AE) than with a sudden onset (40.2%; 1.9 per 1000 AE) and the lower extremities were most commonly injured** (66.7%; 3.2 per 1000 AE), followed by injuries to the head and trunk (25.3%; 1.2 per 1000 AE) and the upper extremities (8.0%; 0.4 per 1000 AE). Detailed injury | **movement patterns and ensuring safe progression with sufficient rest and recovery.** |

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| | | | | | experienced assessor. Skeletal age was determined using the Fels method, following the procedures outlined by Roche et al,25 where a maximal skeletal age of 18.0 indicates full maturity. For prediction of mature height, the TW3 method developed by Tanner et al26 was used. The athlete's TW3 score (max. 1000 points/16.5 years), current stature, and chronological age were entered into the prediction equation to estimate mature height. The intra-rater reliability for Fels skeletal age has previously been reported for this assessor (intraclass correlation coefficient (ICC), 95% CI: 0.998, 0.996-0.999)27 and reliability data from the academy demonstrated an ICC of 0.95 (0.92-0.97) for the TW3 RUS (radius, ulna, and short bones) overall score (unpublished data). staff, following the consensus procedures for athletics outlined by Timpka et al. All physical complaints were recorded by the designated squad physiotherapist based on a standardized injury report form and entered into the | characteristics for location and type are presented in Table 2, and the effects of growth rate, maturity status, and maturity tempo on injury rates are reported in Tables 3 and 4. | |

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| | | | | | Aspire Athletics Injury Surveillance Program database by the senior physiotherapist. Only time-loss injuries were included in the analyses, defined as the athlete not being able to fully take part in athletics training and/or competition the day after the incident occurred (min. 1 day lost). Time-loss injuries were preferred to minimize the potential bias when using multiple injury recorders covering different squads over several seasons. During the study period, six different physiotherapists covered the athletics program, with the same senior physiotherapist in charge of the injury database quality assurance. The number of training and competition sessions (athlete exposures; AE) were entered into a central academy database (Smartabase, Fusion Sport) by the coaching staff and reviewed case-by-case by the senior physiotherapist after each season. | | |
| 15. (28) | Loss of Motor Stability After Sports-Related Concussion: Opportunities for | Avedesian, JM (2021) | Literature review/ expert review of current findings | Moderate | Expert consensus on review of current literature. | See conclusions.<br><br>Numerous injury surveillance datasets have identified an | elevated risk in MSK injury post-concussion is likely secondary to, residual neurophysiological and dual-task motor stability deficits that remain despite RTS-- presents |

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| | Motor Learning Strategies to Reduce Musculoskeletal Injury Risk | | | | | approximate two-fold greater odds for musculoskeletal (MSK) injury following a sports-related concussion (SRC), which may be attributed to residual neurophysiological and neuromuscular control impairments upon return-to-sport (RTS). Following the occurrence of an SRC, evidence from dual-task paradigms **(increased sway and slower gait speed),** neurophysiological assessments (white matter alterations), and athlete self-report (ruminating behavior) contribute to athletes' loss in motor stability and performance that conceptually mirrors an athlete who is at the early stages of motor learning.<br>**Motor learning strategies that purposely employ external focus of attention, enhanced expectancies, autonomy support, variable practice, self-controlled practice, and dual-** | as a loss of autonomous control of gait and posture and an increased need for cognition for motor stability.<br>Inadequate recovery of motor stability (ability to maintain relative position [posture] or trajectory [gait]) before return-to-sport (RTS) has been repeatedly observed.<br>Acquisition of motor skills progresses through three overlapping, but mostly sequential, stages of motor learning: cognitive (first), associative (second), and autonomous (third). Dual-task assessments provide a means to assess the automaticity of motor performance (autonomous stage)--performing a motor and cognitive task simultaneously, and are uniquely designed to redirect explicit attentional resources towards a cognitive stimulus concurrent to a motor task. Athletic environments often require an athlete to perform complex motor tasks while simultaneously engaged with attentional and working memory loads that stress cognitive resources. During locomotion dual-tasks, athletes with SRC demonstrate slower gait velocity, lower step cadence, shorter stride lengths, and greater frontal plane sway relative to uninjured controls during combined cognitive and motor tasks when ambulating-- |

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| | | | | | | **task training may facilitate the restoration of motor stability for a safer RTS following an SRC.** | The SRC-associated motor impairments are further exacerbated when individuals complete dual tasks with greater complexity (return to competitive play). **The increased cognitive demand for basic motor stability may prevent athletes from allocating efficient attentional resources to the concurrent motor skill, thereby reducing their ability to adapt to environmental constraints and potentially impairing lower-extremity biomechanics that expose an athlete to greater injury risk upon RTS.** Reduced motor performance when cognitively challenged after SRC (i.e., decreased lower extremity stiffness, slower gait velocity, and increased postural rigidity) mirrors a loss of autonomous control of fundamental locomotion and postural stability suggesting a regression to the cognitive and associative stages of motor learning.<br>Motor stability recovery may be uniquely suited to ensure neuromuscular control when an athlete returns to sport post-concussion to mitigate MSK injury risk. Motor learning strategies that robustly demonstrate enhanced learning and may uniquely reduce dual-task costs in individuals without SRC to support their adoption as therapeutic options for athletes with SRC—**may be** |

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| | | | | | | | **utilized as prophylactic MSK injury prevention on this notion.** The OPTIMAL (Optimizing Performance Through Intrin-sic Motivation and Attention for Learning) theory of motor learning posits that optimal performance conditions require the presence of three factors: an external focus of attention, enhanced expectancies for future performance, and autonomy support-- directing an individual's attention to their intended movement effect (external focus) relative to their body movements (internal focus) has been shown to robustly improve motor learning and performance irrespective of skill level, task, age, or disability. **External focus (keep wobble board level vs keep feet level) has shown efficacy to improve both motor performance and the trajectory of motor learning over multiple sessions. An external focus lowers overall attentional demands and reduces dual-task costs during motor automaticity tasks.** Providing feedback after good repetitions rather than poor repetitions can promote motor learning by enhancing the learner's confidence for achieving success in the prescribed task. Practice environments that challenge task constraints using **varied and random practice** are uniquely capable of facilitating |

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| | | | | | | | greater motor learning and transferability. |
| 16. (29) | The "SHRed Injuries Basketball" Neuromuscular Training Warm-up Program Reduces Ankle and Knee Injury Rates by 36% in Youth Basketball. | Emery, CA (2021) | Quasi-experimental study.<br><br>Level 4 evidence | Moderate | High school/club basketball teams (male and female players aged 11-18 years) in Calgary, Canada participated in 2016-2017 (control; season 1) and 2017-2018 (intervention; season 2). The control season included a standard-of-practice warm-up. In season 2, a SHRed Injuries Basketball coach workshop was completed by participating team coaches. Teams were randomized by school/club to an unsupervised or a supervised (weekly supervision by study personnel) implementation of the coach-delivered SHRed Injuries Basketball program. The 10-minute SHRed Injuries Basketball program included 13 exercises (ie, aerobic, agility, strength, balance). All-complaint ankle and knee injuries were collected weekly using validated injury surveillance. Multilevel, multivariable Poisson regression analyses (considering important covariates, clustering by team and individual, and | Sixty-three teams (n = 502 players) participated in season 1 and 31 teams (n = 307 players: 143 unsupervised, 164 supervised) participated in season 2. The SHRed Injuries Basketball program was protective against all-complaint knee and ankle injuries (IRR =0.64; 95% confidence interval [CI]: 0.51, 0.79). Unsupervised (IRR = 0.62; 95% CI: 0.47, 0.83) and supervised (IRR = 0.64; 95% CI: 0.49, 0.85) implementations of the SHRed Injuries Basketball program had similar protective effects. | The 10-minute neuromuscular training warm-up comprises 4 components: aerobic and movement preparation (eg, running drills, change of direction), strength (eg, trunk exercises, the Nordic hamstring exercise), agility (eg, hops, jumps), and balance (eg, single leg, dynamic). The SHRed Injuries Basketball neuromuscular training warm-up program was protective against all-complaint knee and ankle injuries for both unsupervised and supervised intervention groups. Coach delivery of a neuromuscular training warm-up following a comprehensive coach workshop is effective in reducing knee and ankle injuries. Players with a previous injury history (1 year) had a 23% higher rate of injury (IRR = 1.23; 95% CI: 1.02, 1.49), and the protective effect did not differ by sex.<br><br>**Neuromuscular and reactive exercises appropriate to implement in warm-ups for games, as well as in training and weight room settings—especially in jump athletes.** |

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| | | | | | offset by exposure hours) estimated incidence rate ratios (IRRs) by intervention group (season 1 versus season 2) and secondarily considered the control versus completion of the SHRed Injuries Basketball program, unsupervised and supervised. | | |
| 17. (30) | Focus of Attention During ACL Injury Prevention Exercises Affects Improvements in Jump-Landing Kinematics in Soccer Players | Dalvandpour, N (2021) | Randomized Control Trial<br><br>Level 2 Evidence | Moderate-high | We conducted a 3-arm, randomized, controlled trial. The selected teams were randomly assigned to 1 of the 3 groups: (a) a group using PEP with instructions focusing on EF, (b) a group using PEP with instructions focusing on IF, and (c) a control group. The 2 intervention groups used the exercises of the PEP program according to the manual by Mandelbaum et al. (22). The program was performed as a warm-up at the beginning of every training session for the duration of 8 weeks. Coaches and players of the 2 intervention groups received 2 different versions of the PEP manual and poster (translated into the local language) according to their focus of attention. Instructions provided in the original | Three teams with a total of 42 players were randomized. Seven players were lost to follow-up and not included in the analysis (see Figure 1 for the complete flow of subjects). Two players were lost to follow-up because they sustained a lower extremity injury during the study, one player was absent during the postintervention test, and 4 players left their soccer club. A total of 35 players were tested postintervention and were included in the analysis. The means and standard deviations of the demographic characteristics of the subjects are presented | Sixty-six percent of soccer injuries occur in the lower extremities, with the knee as the most affected location. ACL injuries commonly occur in sports that require jump-landing, rapid changes in direction and speed, such as soccer, basketball, and volleyball—most occur during occur during a single-leg landing which can create a force on the knee joint as high as 2 – 12 times the body weight and high mechanical stress on the ACL. Recent studies in the field of motor learning have shown that instructions emphasizing an **external focus (EF) are superior over instructions emphasizing internal focus (IF) to learn complex motor skills, such as landing—EF cues fixate on the effect of the movement by directing the player's attention to information that is relevant to the outcome of the movement**. EF group increased the flexion joint angles significantly more over time compared with the IF |

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| | | | | | manual are directed to body movements and the IF of attention (5). An example of the IF cue for the forward/backward hops exercise: " Hop over the cone softly landing on the balls of your feet and bending at the knee. Now, hop backwards over the ball using the same landing technique. Be careful not to snap your knee back to straighten it. You want to maintain a slight bend to the knee. " The IF group used the translated version of this original manual with original instructions. The EF group received our adapted version of the PEP program (i.e., emphasizing an EF of attention) for 8 weeks. A previous study has been used to develop the specific instructions (17). The complete program, including instructions for the EF group, can be found in Supplemental Digital Content 1 (see Appendix 1, http://links.lww.com/JSCR/A297). An example of the EF cue for the forward/backward hops exercise: "Stand behind a 5 cm cone, hop over the cone in front of you, and touch the larger cone next to you | in Table 1. The kinematic characteristics of the preintervention and postintervention tests are presented in Table 2. None of the kinematic characteristics showed significant between-group differences at baseline. The results of the repeated-measures ANOVA are presented in Table 2. A significant time by group interaction effect was found for hip flexion at initial contact ( $p < 0.001$), at peak VGRF ($p=0.031$), and at maximum knee flexion ( $p=0.010$). The effect size was large at all time points during landing that we analyzed, with h2-values ranging from 0.16 to 0.26 (Table 2). The EF group showed higher increases in hip flexion angle after the 8-week intervention compared with the other 2 groups at all points during the | and control groups. The results show an effect **favoring the EF group on the knee and hip joint angles at the initial contact, peak VGRF, and maximum knee flexion**.<br>EF superiority theorized due to **the attention in EF attracting the athlete to the effect of the movement into the environment, which facilitates automated control processes,** which improves motor learning. Whereas IF instructions foster conscious control and consequently disrupt the automated control process.<br>**EF instruction improves hip and knee joint kinematics in the sagittal plane during landing and seems to improve the kinematic variables of the lower extremities to reduce the risk of ACL injury.**<br><br>***EF may be important factor to develop neuromuscular control via automated control (autonomous stage of motor learning)—highest level of motor learning.*** |

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| | | | | | with your hands as you land. The heel of your foot should not touch the line along the path. ” The control group followed their usual warm-up program. An a priori sample size estimation revealed that 33 players (11 in each group) were required to provide meaningful results with an effect size of 0.3, a power of 0.85, and alpha level set at 0.05 using repeated-measures analysis of variance (ANOVA) to analyze the data. All clubs competing in the U21 Iranian premier league (8 clubs) were invited to participate in the study. Three of the 8 interested clubs were selected randomly. In this randomized controlled trial, 42 male soccer players (age range, 17 – 19 years; The height, weight and age are reported with SD ) from these 3 teams fulfilled the inclusion criteria and volunteered to participate. Inclusion criteria for the players were at least 3 training sessions per week, no hip, ankle, and knee injuries in the past 6 months (including chronic tendinopathy, | landing that were analyzed. No significant changes in hip flexion angle were found in the IF and control groups. A significant group * time interaction effect was found for the knee flexion angle at the initial contact and at maximum knee flexion ( $p < 0.001$ for both) with $n^2$-values of 0.42 and 0.36, respectively, the effects are considered large. Also here, the increase in knee flexion angle was significantly greater in the EF group compared with the other 2 groups, where no significant change over time was observed. Additionally, a significant main effect of time with a moderate effect size was found for the knee external rotation angle at peak VGRF ($p = 0.040$; $n^2= 0.12$) and for the hip external rotation angle at the initial contact ($p = 0.039$; $n^2= 0.12$). | |

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| | | | | | muscle strain, and ligament sprain injuries), and no history of lower-limb surgery. Before the start of the study, all subjects and their parents or legal guardians were fully informed about the risks and benefits of the study. Parents of players younger than 18 years and players who were 18 years and above provided their written informed consent using an institutionally approved form. Players younger than 18 years provided their written assent using an institutionally approved document. Ethical approval was obtained from the institutional ethics board Iran National Ethics Committee on Biomedical Research. | | |
| 18. (31) | Prevention of noncontact ACL injuries in women: use of the core of evidence to clip the wings of a "Black Swan". | Hewett, T (2009) | Literature review and expert opinion<br><br>Level 5 Evidence | Moderate | Literature review and expert commentary. | See conclusions. | Most of the available evidence indicates that prophylactic interventions that target underlying mechanisms of ACL injuries can decrease risk. Intrinsic mechanisms include anatomical, hormonal, and most importantly, neuromuscular factors. Neuromuscular mechanisms should be emphasized because they are the intrinsic factors that appear to have the greatest effect and the only ones we can readily alter. collegiate women athletes |

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| | | | | | | | who do not **sense or control their trunk position well in three-dimensional space had significantly higher risk of future knee and ACL injury**. Current theory is that pubertal growth in the absence of a neuromuscular spurt results in neuromuscular imbalances that directly underlie the ACL injury mechanism. These observed neuromuscular imbalances give important clues for guiding prevention program strategies—***need for sufficient S&C in female high school/ MS athletes.*** Tendency for women to be ligament-dominant-- refers to the absence of muscle control of medial- lateral knee motion that results in high valgus knee torques and high ground reaction forces. A second common imbalance is referred to as quadriceps dominance-- preferentially activate their knee extensors over their knee flexors and gluteal muscle groups to stabilize their knee during movement, which perpetuates strength and recruitment imbalances between these muscles. Yet another imbalance is leg dominance, which is characterized by one leg with weaker and less coordinated hamstring musculature than the other. A final observed imbalance can be termed trunk dominance, in which the momentum of the trunk is not controlled sufficiently, |

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| | | | | | | | which leads to uncontrolled motion of the center of mass during deceleration and movement of the ground reaction force vector to the lateral side of the joint. ***Each of these can and should be addressed in training and in women's S&C.*** ACL injury is a multiplanar injury, and the sports movements that cause them likely occur in all three planes of motion. |
| 19. (32) | Adolescent athletes demonstrate inferior objective profiles at the time of return to sport after ACLR compared with healthy controls. | Robinson, JD (2022) | Cross-sectional study<br><br>Level 3 Evidence | Low-moderate | Included were 124 participants; 62 patients who underwent ACLR (15.4±1.7 years) and 62 healthy controls (15.3± 1.7 years). Motion capture and force plates were used to capture joint motions during jump landing (JL) and single-limb squat (SLS) tasks. Energy absorption contribution (EAC) was calculated, and repeated-measures analysis of variance was used to assess for EAC differences between groups. Participants completed an International Knee Documentation Committee (IKDC) Subjective Knee Form, and isokinetic quadriceps and hamstring strength testing was performed on each limb. Independent t-tests were run to examine age, height, weight, and IKDC scores | A significant group joint interaction was found for JL (P<.001) and SLS (P<.001). For JL, patients who underwent ACLR utilized significantly greater hip (P<.001) and significantly less knee (P<.001) EAC on the surgical limb compared with controls. During SLS, patients who underwent ACLR utilized significantly greater hip (P<.001) and significantly less knee (P<.001) EAC on the surgical limb compared with controls. The ACLR cohort demonstrated lower IKDC scores (P<.001) and significantly lower quadriceps strength on the surgical limb | ACL RTS rates for competitive sports are relatively low, reporting at 55% at 1 year and approximately 65% at 2 years--may be related to multiple factors, including persistent **deficits in muscle strength, athletic performance/level, and altered limb-loading strategies during squatting, jumping, and landing activities.** Some compensatory strategies not seen until athletes attempts to RTS. **Decreased knee extension moments and smaller knee flexion and hip adduction angles are present during the single-limb squat (SLS) in patients who have undergone ACLR** when compared with healthy controls at approximately 7 months postoperatively, and **lower vertical ground-reaction force, decreased energy absorption, and deficits in external knee extension moments compared with the nonsurgical limb during a drop jump landing (JL) task**. |

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| | | | | | as well as compare differences between groups for quadriceps and hamstring strength. | (P<.001) than controls. There were no differences in surgical limb hamstring strength between the ACLR cohort and healthy controls (p=.701).<br><br>Clinicians should recognize inherent "unseen" asymmetries and consider the intralimb and between-limb motor pattern alterations that may be used to achieve symmetry during a double-limb task.<br><br>The limb symmetry index was found to be 73.7%for quadriceps strength in patients who underwent ACLR—ideally 95%+ for RTS criteria. | **For quadriceps strength, the ACLR group demonstrated significantly lower surgical limb values. after ACLR would demonstrate alterations in surgical limb loading, and deficits in quadriceps strength values and self-reported measures of function** when compared with matched healthy controls. They also demonstrated an increase in hip loading with a subsequent decrease in loading at the knee on the surgical limb compared with healthy controls during both the jump-landing (JL) and single-limb squat (SLS) tasks—**likely compensatory strategy due to lack of trust in knee.**<br>The surgical limb in patients who underwent ACLR demonstrated increased hip and decreased knee energy absorption contribution (EAC) during both SLS and JL tasks.<br>ACLR group continued to demonstrate consistently diminished knee EAC in the surgical limb at the time of RTS with more demanding maneuvers, which may be explained by a lack of quadriceps strength as well as continued neuromuscular control deficits of the extremity—**neuromuscular control deficits seen with increased level of physical challenge.**<br>The differences in limb EAC during the JL across the matched |

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| | | | | | | | nonsurgical limbs of the cohorts may illustrate variable intralimb compensation strategies depending on limb dominance-- nonsurgical/matched limb of both groups is essentially forced to compensate for alterations that might occur on the ACLR limb. Quad/ HS muscle co-contraction use to minimize dynamic knee valgus and knee abduction. Deficits in hamstring strength may ultimately diminish co-contraction about the knee and increase ligamentous stresses (ie, ACL shear stress) with the resulting dynamic instability-- **quadriceps strength deficit may lead to intralimb compensations and contribute to altered EAC patterns across the kinetic chain.** |
| 20. (33) | Anterior cruciate ligament injury mechanisms through a neurocognition lens: implications for injury screening. | Gokeler, A (2021) | Literature review and expert opinion<br><br>Level 5 Evidence | High | Literature review performed | See conclusions.<br><br>To enhance ACL injury screening test validity, these tests should also include neurocognitive demands: Stroop task, Flanker task, go/no-go tasks and the stop-signal task, N-back task, forward or backwards- digit span tasks and the Corsi block test.—proposition of an integrated and therefore complex assessment with | In team ball sports, the athletes are immersed in a rapidly changing, unpredictable and externally paced environment. In these open-skill sports, perception-action coupling is crucial, as the athlete has to perceive their own action opportunities as well as those of opponents and teammates before deciding on a movement solution, all of these often under time pressure. Deficit or delay in sensory or attentional processing may lead to potential coordination errors and result in high-risk knee movements under high temporal constraints, posing a challenge to maintain coordinated control of movements—**highlights need for** |

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| | | | | | | open-skill motor tasks where neurocognitive demands are added.<br><br>*Training that incorporates and stresses reactive, inhibitory control, and working memory components of neurocognitive movement strategies may be beneficial to injury reduction efforts.* | **random practice and variable responses in training.** Executive functions are essential in tasks that demand **concentration, coordination and control to override internal or external stimuli-- the ability to coordinate cognitive, emotional and motor processes** as the set of adaptive behaviors allowing people to **successfully navigate the environment by shifting and adapting to changing environmental cues and needs**. **Inhibitory control** involves the ability to control attention, behavior, thoughts and/or emotions in order to cancel strong internal predispositions or external temptation, and instead act in a more appropriate way-- plays an important role in **selective attention, that is, the deployment of attentional focus on task relevant features of for example, the rapidly changing situations on the field.** Performance in sport constitutes a combination of both motor and perceptual- cognitive skills, which address an athlete's ability to locate, identify, and process information in a specific environment-- requires quick and effective perception and interpretation of the opportunities to execute the successful performance. Athletes must be able to **predict the outcome of deceptive moves.** In a fraction of |

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| | | | | | | | a second, the defender has to change the movement quickly which poses a **significant challenge for the motor system to change an already planned or initiated movement.**<br>Lacking the capability to redirect or sustain attention from one stimulus to the next may result in a **loss of spatial awareness and disrupt motor control**-- less attention for the athlete's own movements and may contribute to the ACL injury mechanism, as less time is available to correct or change an already initiated movement. **Cognitive processes during team sports do not only rely on reactive patterns, but also on working memory and inhibitory control where information needs to be stored and distractors need to be ignored.** |
| 21. (34) | Mechanisms, prediction, and prevention of ACL injuries: Cut risk with three sharpened and validated tools. | Hewett, T (2016) | Literature review and expert opinion<br><br>Level 5 Evidence | high | Literature review performed | See conclusions.<br><br>Safe attenuation of landing forces and efficient neuromuscular control (recruitment of muscular restraints to resist perturbations and control dangerous external loads to the lower extremity) is essential for the prevention of injury during sports. | Strong association between ACL injury and development of posttraumatic knee osteoarthritis at a relatively young age (even within 10 years of initial injury), which also occurs with much greater incidence in females than males. Most ACL injuries in females occur by non-contact mechanisms during landing and lateral pivoting. Female athletes have a 2–8 fold greater ACL injury rate compared to male athletes and it is estimated that 5% of female high school varsity athletes per year sustain a primary |

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| | | | | | | Rehabilitation programs that target reduction in functional asymmetries prior to the return to sports after ACL reconstruction may be necessary to more safely reintegrate these patients back to sports—**similar guidelines for reduction strategies.**<br><br>“ligament dominance,” can be defined as an imbalance between the neuromuscular and ligamentous control of dynamic knee joint stability—increase need for active stabilizers.<br><br>**The adolescent phase is a critical stage for neuromuscular control development during which children may overcome certain deficits or develop new ones. If not addressed, neuromuscular deficits may continue into** | ACL injury—**hypothesized by decreased training time and strengthening compared to male athletes (modifiable risk factor)**. Post-pubertal females exhibit greater landing forces and force loading rates, lower hamstrings to quadriceps torque ratios at high angular velocities and altered quadriceps and hamstrings activation strategies compared to males. Females may preferentially rely on higher activations of quadriceps muscles relative to hamstrings muscles with incremental increases in landing intensities—same contributions as above. No effect of either the menstrual cycle or hormone stabilization (oral contraceptives) on knee or hip joint loading during high risk sport maneuvers—unclear if it is contributory. For females, the absence of a neuromuscular spurt potentially increases knee injury risk due to possible deficiencies in neuromuscular control and the ability to adapt to perturbations to the longer bony levers and greater mass that accompanies the maturation process—**necessitates neuromuscular training.**<br>Core body control and lower extremity proprioception are modifiable risk factors and are important for attenuating and adapting to perturbations during sports tasks. ACL reconstructed patients cleared to return back to |

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| | | | | | | **adulthood and increase an athlete's risk for ACL injury—<u>need for exposure to multiplanar and complex movement strategies at a younger age.</u>** | sports **frequently exhibit patterns of favoring their uninjured contralateral limb and this deficit may persist even after 2 years post-operatively—increased risk for contralateral limb injury**. ACL injuries are **more likely to occur during multi-planar rather than uni-planar mechanisms**. Mechanism of valgus collapse mechanism with potential multi-planar loads of tibial abduction combined with anterior tibial translation or external or internal tibial rotations. |
| 22. (35) | Estimating knee dynamics during landing | Tait, D (2021) | Meta-Analysis and Systematic Review<br><br>Level 1 Evidence | Moderate to high | Electronic databases Medline, EMBASE, CINAHL, Web of Science and Cochrane were screened for studies that included measurement of initial contact angles and internal joint moments of both the ankle and knee during landing in uninjured individuals. | 28 studies were included for analysis. Using 1144 landing trials from 859 individuals, RRelief F algorithm ranked dynamic ankle measures more important than landing task and subject characteristics in estimating knee dynamics. An adaptive boosting model using four dynamic ankle measures accurately estimated knee extension ($R^2$ = 0.738, RMSE = 3.65) and knee abduction ($R^2$ = 0.999, RMSE = 0.06) at initial contact and | At initial contact (IC) in landing, minimal ankle plantar flexion, less ankle excursion and a shorter time interval between IC and heel contact, have all been observed during on field ACL injury incidents compared to similar, within-game landing maneuvers. Greater plantar flexion angles at IC have been associated with lower ground reaction forces (GRF)-- greater availability of range can increase the capacity for shock attenuation and is correlated with a lower peak loading rate—**need for adequate ankle-controlled ROM to neutral (eccentric loading), view LEs as a chain that impact one another in CKC activities. Force attenuation in the chain important to reduce impact up the chain at knee.**<br>Results of this study found that dynamic ankle measures were |

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| | | | | | | peak knee extension moment ($R^2 = 0.988$, RMSE = 0.13) and peak knee adduction moment ($R^2 = 1$, RMSE = 0.00). | more important than both landing tasks and subject characteristics, in estimating dynamic knee measures across 1144 landing trials-- knee and ankle interactions are similar across a variety of vertical landing tasks and population groups. **The ankle's response to vertical landing can be predictive of the positions and moments experienced by the knee-- the ankle is the first major joint to absorb energy during landing and it's in fluence over the knee has been described through numerous mechanisms. Plantar flexor (PF) muscles offer a stabilizing role over the knee and affect ACL loading as they alter magnitude and direction of GRFs during the initial stage of landing**-- due to the **biarticular nature of gastrocnemius** in terminal knee extension and its ability to preempt contact through its pre-activation sequencing prior to landing—**gastroc (PFs) crosses knee joint and soleus produces posterior tibial forces during PF when foot on ground— <u>necessitates plyometrics to train eccentric loading of PF group.</u>** The ankle's work contribution to landing can be improved through increased IC plantar flexion angles, which have also been seen to promote greater overall muscle activation throughout the lower extremity and lower peak loading rates during landing. |

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| 23. (36) | If overuse injury is a 'training load error', should undertraining be viewed the same way? | Gabbett, T (2016) | Literature review and expert opinion<br><br>Level 5 Evidence | low | Literature review performed. | See conclusions. | Training that focuses on the average demands of competition results in athletes being **underprepared for the most extreme passages of play.** |
| 24. (37) | Damaging nature of decelerations: Do we adequately prepare players? | Harper, D (2018) | Anecdotal evidence, expert opinion<br><br>Level 5 Evidence | Moderate-High | Expert opinion based on anecdotal evidence with literature review. | See conclusions.<br><br>the load per meter experienced during decelerations is up to 65% greater (effect size=2, very large) than any other match play activities, and approximately 37% more than when accelerating.<br><br>Resilience to deceleration activity can be augmented via (1) increasing the load-bearing capacities of lower limb tissues, and (2) nurturing the coordinative skill of deceleration by exposing players to challenges enhancing more sensitive and accurate calibration of the muscular co-contraction patterns, and limb positioning strategies, essential to proficient | Accelerations occur within low to moderate intensity ranges, where decelerations occur more within high-intensity thresholds--decelerations are up to 2.9 times more frequent than high-intensity accelerations. A large proportion of decelerations **are suddenly imposed, thereby enforcing rapid velocity reductions within constrained timeframes and spaces**. The sudden braking activity implicit in severe decelerations **demands intense eccentric and quasi-isometric contractions, which are capable of generating higher muscular tensions** than concentric actions see with accelerations. The fatigue and cumulative tissue microtrauma imposed following deceleration activities are greater than that following similarly intense accelerations. The mechanical stressors, implicit in deceleration activities, are critical mediators serving as potent drivers of both neuromuscular fatigue and tissue damage-- both act to further diminish the coordinative capacities underpinning an ability to skillfully dissipate braking loads—**highlights need for** |

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| | | | | | | deceleration activity. **FIGURE 1** | **<u>progressive overload of deceleration principles to adapt in offseason, and to decrease competition volumes in season (year round single sport participation.) FIGURE 1</u>** Optimal match play preparation should include incrementally progressive exposure to deceleration loadings-- regular and sensitive monitoring of deceleration-induced load , and subsequently imposed decrements. |
| 25. (38) | What have we learnt from quantitative case reports of acute lateral ankle sprains injuries and episodes of 'giving-way' of the ankle joint, and what shall we further investigate? | Lysdal, F (2022) | Systematic Review<br><br>Level 1 Evidence | Moderate-high | The authorship group already had a good knowledge of the existing literature within this area, by virtue of being the authors of most of the published case reports. However, to reduce the risk of missing other published cases, a literature search was conducted. EMBASE and OVID search tools were used to systematically screen records within MEDLINE® and EMBASE® including the following possible status besides MEDLINE and EMBASE: Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Daily and Versions(R) 1946 to present, with a final | The systematic search process (Supplementary Appendix 1) produced a total of 81 potentially eligible articles after duplicates were removed ( Figure 1 ). Of these, 51 were directly excluded in the title and abstract screening, while additional four reports could not be retrieved. Of the 26 reports assessed for eligibility, 13 were excluded: Ten reports did not contain kinematic or kinetic outcomes of the described event, two for being medial ankle sprain analyses (X. Li et | Lateral ankle sprains are the most common injury incurred by individuals who participate in sports, they have a high recurrence rate, are often compounded by the development of persistent injury-associated symptoms. **Proposed mechanism is plantarflexion and inversion, which predisposes ATFL to increased strain, CFL secondary injury common.** The 22 cases reporting ankle inversion and plantarflexion angles had an average initial contact inversion angle of 8.2 degrees and initial plantar flexion angle of 9.3 degrees-- inversion angle reached an average peak inversion of 66.5 degree after 0.20 seconds. 2 distinct peaks in ankle inversion angle discovered during initial contact: The first peak occurred between 30 and 80 milliseconds after foot strike, and the second peak between 100 and 200 milliseconds (Figure 4). |

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| | | | | | search being conducted on 7 October 2021 using the following search string in MEDLINE: (ankle[Title] AND sprain[Title] OR giving-way[Title]) AND (case[Title] OR cases[Title] OR episode[Title] OR episodes[Title] OR accident[Title] OR accidents[Title] OR accidental[Title] OR recorded[Title] OR captured[Title] OR televised[Title]) , and (ankle:ti AND sprain:ti OR 'giving way':ti) AND (case:ti OR cases:ti OR episode:ti OR episodes:ti OR accident:ti OR accidents:ti OR accidental:ti OR recorded:ti OR captured:ti OR televised:ti) in EMBASE. Additional non-systematic searches were conducted in Google Scholar and other general search engines. Unpublished laboratory-recorded lateral ankle sprains, twists, and episodes of giving-way were invited for inclusion in this review by informally | al., 2016 ; Wade et al., 2018 ), and one for being a conference abstract of an included case report (Chin et al., 2020 ). The 13 included studies were accompanied by two additional reports retrieved via other methods: One case from within the authorship group (Lysdal et al., 2018), and one case presented at the 38th Conference of the International Society of Biomechanics in Sports, and retrieved from the conference proceedings (Trejo Ramírez et al., 2020). | Giving-way of the ankle joint reported distinct counteracting movements during the episodes--**the inversion phase of the ankle joint was followed up by a faster and more significant correcting eversion—** **<u>neuromuscular action of peroneals to counteract strain force</u>**.<br>**Higher chance for time lost post-injury in game settings vs trainings**-- likely explained by the less vigorous intensity also observed in training compared to match play.<br>multiple cases in this review occurred despite the ankle joint being in an initially everted position—abnormal from typical presentation-- **suggests that the very first instance of initial contact might not be as critical as the first few milliseconds that follow immediately after initial ground contact.**<br>Incident might be most likely to occur during absorption, during propulsion, as well as during the transition in-between the two phases.<br><br>**<u>Demonstrates need for neuromuscular and landing training, eccentric and SL phasing to improve landing mechanics to mitigate risk factors.</u>** |

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| | | | | | asking around in scientific communities. | | |
| 26. (39) | Bilateral vs. Unilateral: The Great Squat Debate | Hill, D (2022) | Blog Article<br><br>Level 5 Evidence | Moderate | Anecdotal blog evidence with references | See conclusions.<br><br>Deep back squats are correlated with the improved thickness of the ACL and connective tissues within the knee. Whether or not you can squat a lot, performing regular deep squats through adolescence seems to grow this essential tissue.<br>Improving the squat is associated with increased vertical and improved sprint times. You don't have to lift a house to see benefits from getting stronger. Likewise, bilateral training might impact things that require more strength, such as change of direction and deceleration. Bilateral performance training seems to have a greater magnitude for performance increases with a longer impact duration. While | Unilateral training is a critical component in building transferable performance-- mimics the hip angles of sprinting. This is most likely why some research finds that unilateral strength training (even with less weight) can create nearly equal performance gains as bilateral strength training. Bilateral squats are in a balanced and controlled environment that allows for greater voluntary contraction, force, and power without worrying about balance-- significant drawback of unilateral training is the inhibitory component of finding your ground. Max contraction, and possibly max force, is easier to train from a bilateral stance. Decreased weight in unilateral squatting allows for an increase in training volume to match intensity of bilateral heavy lifts. Squatting should have little to do with how much they lift and more with how much more they can correctly do than when they started—**form over weight. Unilateral training and bilateral training improve performance, but the combination of the two ultimately creates the best results**. |

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| | | | | | | research shows unilateral training has rapid, short-term gains (less than six weeks), bilateral development has a slower but greater and longer-lasting process (12+ weeks). | |
| 27. (40) | Eccentric Training and the Younger Athlete | Baker, J (2022) | Blog article<br><br>Level 5 Evidence | Moderate-high | Anecdotal evidence | See conclusions.<br><br>**Starts with lower eccentric loads introduced through basic jumping and landing tasks once movement competency in basic movements is established. Following this, we can gradually increase the intensity of the eccentric overloads—keeping an eye on movement quality as the young athlete grows and matures.** | Eccentric training for young athletes needs to be appropriately progressed and developed over time to ensure they are able to reap the benefits without getting injured. Establish movement competency first and then we build up the athlete's ability to tolerate some volume using their body weight alone. From there, we begin to introduce variation in the speed of the execution of the movements, including increasing the time under tension with tempo controls. This includes slower eccentric phases and isometric holds in the base of squats and split squats. first progression in the eccentric loading is to introduce time under tension, but under load in the general strength exercises. Then we increase the height of the altitude landings while challenging the athletes to increase the stiffness in landing by reducing the amount they yield at the ankle, knee, and hip on impact.<br>The athletes are challenged here to control and absorb landings over greater heights and distances, and |

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| | | | | | | | also to repeat them in a sequence (e.g., repeated broad jumps). |
| 28. (41) | It's not all about sprinting: mechanisms of acute hamstring strain injuries in professional male rugby union-a systematic visual video analysis. | Kerin, F (2022) | Systematic Visual Video Analysis<br><br>Level 3 Evidence | | All time-loss acute HSIs identified via retrospective analysis of the Leinster Rugby injury surveillance database across the 2015/2016 to 2017/2018 seasons were considered as potentially eligible for inclusion. Three chartered physiotherapists (analysts) independently assessed all videos with a consensus meeting convened to describe the injury mechanisms. The determination of the injury mechanisms was based on an inductive process informed by a critical review of HSI mechanism literature (including kinematics, kinetics and muscle activity). One of the analysts also developed a qualitative description of each injury mechanism. | Seventeen acute HSIs were included in this study. Twelve per cent of the injuries were sustained during training with the remainder sustained during match-play. One HSI occurred due to direct contact to the injured muscle. The remainder were classified as indirect contact (ie, contact to another body region) or non-contact. These HSIs were sustained during five distinct actions-'running' (47%), 'decelerating' (18%), 'kicking' (6%), during a 'tackle' (6%) and 'rucking' (18%). The most common biomechanical presentation of the injured limb was characterized by trunk flexion with concomitant active knee extension (76%). Fifty per cent of cases also involved ipsilateral trunk rotation. | Hamstring strain injuries (HSIs) are the most prevalent muscle injury sustained by professional field-sport athletes. those that occur during sprinting (sprint-type) are a result of an 'over-stretch' (stretch-type)—**eccentric overload during the terminal swing phase of high velocity running. During terminal swing, biceps femoris ~110% of resting length.**<br>The Stretch type of HSIs typically occur as a result of an over-stretch in a position of knee extension and trunk flexion—**elongation on both ends of HS.**<br>12% of injuries occurred in training vs 88% in competition. 94% of injuries were non-contact actions such as accelerating, decelerating, kicking, during a tackle and rucking vs 6% direct contact trauma injuries. Injuries that involved a **change of direction occurred while the athlete turned away from the injured side**. Injuries that occurred during locomotion (running and decelerating) were deemed to have occurred during the late swing phase. In con-contact HSI's, the knee of the injured limb was undergoing angular extension. The **hip was deemed to be extending** in all cases, except for during 'tackle' |

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| | | | | | | | and 'rucking' mechanism. In all non-contact or indirect contact cases, the player was in a position of trunk flexion. **Trunk rotation** was commonly observed, with ~50% injuries characterized by rotation towards the injured **(ipsilateral) side—pelvic rotation elongates proximal HS.** During running, most injuries occurred while the player was accelerating rather than during maximum velocity running—**necessitates need for acceleration training.** Greater extension moment at the hip and power absorption at the knee during that late swing phase in players who would subsequently incur HSIs—**mechanical disadvantageous position of hip extensors with trunk and hip flexion.** Trunk rotation is likely to be a manifestation of 'overstriding' and may increase **the net negative (ie, eccentric) work required by the hamstring muscle**s during the terminal swing phase, thus potentially increasing the risk of HSI. In deceleration injuries, the injured player was in a position of trunk and hip flexion, with the ipsilateral knee moving towards extension or in a position of shallow knee flexion. This lengthened position of the hamstring muscles across two joints may heighten the risk of HSI |

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| | | | | | | | during deceleration, especially considering that **rapid hamstring contraction is integral to efficient deceleration—importance of eccentric HS strengthening for decelerations.** 'kicking' HSI mechanism replicates the 'stretch-type' HSI mechanism-- which is characterized by a position of trunk flexion and ipsilateral (ie, injured limb) hip flexion, with a rapid active knee extension. Failure to appropriately consider trunk sensorimotor control during HSI prevention and rehabilitation protocols may explain the perennially high rates of HSIs—**necessitates need to train trunk and sensorimotor control.** Prevention strategies should include a **combination of hamstring loading at long lengths,** but which also **simultaneously challenge multiplanar trunk stability**. |
| 29. (42) | Mitigating the Dreaded Ankle Sprain | Foley, D (2022) | Blog Article<br><br>Level 5 Evidence | High | Anecdotal evidence with references | See conclusions<br><br>**The inability to load eccentrically through the foot places more undue stress on surrounding structures—which includes the ankle. The longer an athlete goes without addressing the eccentric deficit, the** | Several factors at play with ankle and foot injuries: footwear, surface type, age/phase of development, speed/direction of applied force, and even environmental conditions which can all influence injury. Ankle/foot injuries represented roughly 40% of the total lower-extremity injuries reported. Developing foundational foot strength, including a good bit of barefoot training, addressing lower leg muscles directly, and emphasizing proprioception across |

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| | | | | | | **more likely they are to develop common overuse injuries** such as turf toe, plantar fasciitis, achilles tendonitis, or chronic ankle sprain development. | exercise selections. Improving foot eccentric strength and motor control are among the most critical but ignored aspects of sport performance-- human movement starts from interaction with the ground (ground reaction forces—GRF)-- **more evenly distributed forces, capable of producing and tolerating greater force magnitudes, also less likely to have issues with overloading or overstressing specific regions of the foot.—<u>decreases torque when accommodating GRF</u>**.<br>With weak foot eccentrics, ankle forced to control extra ROM due to lack of stability of foot.<br>The best way to start is by simply having your athletes get out of their shoes for portions of their training. The peroneal group, which spans the lateral compartment of the lower leg, plays an essential role in stabilizing the ankle/foot complex. The TA is a primary dorsiflexor while assisting in foot inversion and **acts to eccentrically stabilize the tibia during rapid plantarflexion.**<br>Fibrous tissues provide proprioception, balance, motor control, sensory function, and neuromuscular function. It's imperative to recognize that these receptors are not stimulated (at least not significantly) during conventional bilateral movements with limited mechanical |

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| | | | | | | | deviations. Moreover, there is a reduced proprioceptive demand as familiarity to certain movements/exercises increases. Sensory-motor elements of ankle and foot gives the athlete a better sense of trust and confidence in the joint. |
| 30. (43) | CAN WE PREVENT ACL INJURIES? | Mandala, T (2021) | Literature Review<br><br>Level 5 Evidence | Moderate | Literature review | Se conclusions.<br><br>programs that include these components have been shown to:<br><br>Reduce the risk of ACL injury in athletes by 43%<br><br>Reduce the risk of noncontact ACL injury by 73% | The most effective ACL prevention programs were performed at least twice/week for periods > 20 minutes as a time. Successful programs focused on strength training of the lower extremity, especially the quadriceps-- shown to decrease ACL injury risk substantially. **After ACL surgery, every 1% increase in quadriceps strength led to a 3% reduction in re-injury rate.** Examples: open chain knee extension (similar to quad strength test position), RFESS, plyometrics (bounding, landing mechanics, core stability/deceleration control. |
| 31. (44) | ACL injury prevention strategies for any coach | Welch, N (2022) | Literature review<br><br>Level 5 evidence | Moderate-high | Literature review | See conclusions.<br><br>Cant trade off performance for prevention. | ACL injuries result from excessive rotational loading through the joint causing strain and shear loading high enough for the ligament to rupture. Wider foot plants, greater angles of hip abduction, greater foot external rotation, greater ipsilateral trunk sway and greater knee extension all relate to increased rotational knee loads. Performance factors that contribute to increased knee rotational loading during change of direction-- greater velocities, |

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| | | | | | | | greater ground reaction forces and greater angle of cut.<br>Reduction of trunk sway reduces rotation loading about knee.<br>Greater hip flexion and knee flexion, or being closer to your athletic stance, will reduce rotational knee loading during the cut-- the further you deviate upwards from your athletic stance at every stage of the cutting task, the greater the risk of injury.<br>Leaning and rotating the trunk in the direction of the cut, maintaining a lower center of mass and resisting movement of the center of mass towards the plant foot (think lateral stiffness), short ground contact times and early force production are also associated with faster cuts, both of which require greater pre-activation and/or co-contraction – (may also be protective) are all associated with a faster cut time-- opposite of the technical risk factors for ACL injury-- performance and injury prevention are not mutually exclusive.<br>In sport-specific defensive scenarios and at slower speeds, athletic stance will be lower than at higher speeds and in attacking cutting actions-- need to be able to do it forwards, backwards, sideways and in rotational movements, and move seamlessly between them all, as well as from stationary starts and while moving at speed. Train transitions from |

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| | | | | | | | movement pattern to movement pattern (shuffle to backpedal to forward run etc)—both blocked and random practice. |
| 32. (45) | ACL injury prevention: Where have we come from and where are we going? | Arundale, A (2021) | Literature Review of best evidence<br><br>Level 5 Evidence | Moderate-high | Literature review | See conclusions. | proximal control exercises (defined as exercises that involve segments proximal to the knee joint) seem to improve the efficacy of ACL injury prevention plans (IPPs). Frontal and transverse plane biomechanics, such as medial knee displacement45or valgus collapse (hip adduction, hip internal rotation, and knee abduction),46,47may be associated with ACL injuries.<br>Augmented neuromuscular training program led to decreases in hip adduction during cutting, which was related to decreased activity in knee sensory – visual – spatial and motor planning areas, and that decreases in hip adduction and knee rotation were associated with decreased motor cortex activity-- greater efficiency in processing, potentially improving the transfer of practiced patterns to complex sporting environments.<br>External cues, directing the athletes' attention outside their body or to the outcome can facilitate changes in biomechanics.<br>It is more cost - effective, both in implementation as well as in future healthcare costs, to provide ACL IPPs to all athletes than to screen and select at - risk athletes.<br>One successful strategy to bolster adherence is to let the IPP act as a |

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| | | | | | | | warm-up. After a shortened preseason or preparation (COVID), athletes are at a higher risk for injury. |
| 33. (46) | A Case for Skipping Rope in Sports Training | Avila, E (2022) | Blog with references<br><br>Level 5 Evidence | moderate | Evidenced based blog | See conclusions. | Jumping rope (JR) leads to improved footwork comes from developing the ability to move off the balls of the feet (metatarsals) rhythmically. Improved footwork's balance and coordination lends itself to improving speed. JR is sustained for an extended period-- it helps develop the cardiovascular system. JR allows athletes to transition seamlessly between aerobic and anaerobic work. Rope training was shown to be effective on heart rate and anaerobic characteristics. The jump rope is simplistic in the way it helps develop total body coordination—the moment an athlete loses sync with their rhythm, the rope comes to a stop. In this sense, it's a self-correcting tool for developing coordination, as the rope will give immediate feedback when the athlete's jumping isn't in sync. **Bouncing with JR helps develop the stretch-shortening cycle (SSC) necessary as a base for eccentric strengthening of the LEs-- stretch phase of the eccentric contraction maximally activates the muscle, for a more forceful concentric contraction—<u>elastic component of landing</u>**. Plyometrics can greatly tax athletes and, in certain instances, |

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| | | | | | | | some athletes may not even be prepared to utilize them in their training programs. Using a jump rope can be an effective method to train the SSC, especially during the early phase of a program with younger athletes or those coming back from an injury—**JR for early development of plyos and for early return to plyos—basis of progressive overload for SSC.** For anaerobic work, some possibilities include different timed sprint intervals with the rope (timed sprints with JR).<br>Energy Systems:<br>Aerobic work can follow the typical parameters of slow steady-state work done at a moderate intensity. HIIT type work is another effective way to get a mix of both conditioning systems in a workout.<br>Coordination:<br>A progression from these footwork patterns can involve a coach (or the athletes themselves) calling out different patterns during a rope skipping training session and having the athlete alternate between patterns while maintaining a rhythm. |
| 34. (47) | Rehabilitation and Return to Sport Testing After Anterior Cruciate Ligament Reconstruction: Where Are We in 2022? | Gokeler, A (2022) | Expert Opinion and Literature Review<br><br>Level 5 Evidence | Moderate | Literature review | See conclusions.<br><br>Between 9 months and 2 years after surgery, there was no significant reduction in the risk for second knee injuries— | Patients who were about to undergo a primary ACLR had high expectations for return to their preinjury level of sport, with 88%, only 65% of patients after ACLR return to their preinjury level of sport-- greater risk for a second ACL injury for the active, young |

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| | | | | | | impairments and asymmetries may be present for up to 2 years post injury—don't rush back to RTS. | athlete ( < 20 years) who resumes activity after ACLR. Only 23% of patients after ACLR passed RTS test batteries before RTS. A RTS battery should at least include strength tests, hop tests, and measures of quality of movement.<br><u>Muscle Strength:</u><br>Handheld dynamometry (HHD)> MMT for RTS. Limb symmetry index (LSI) is used, defined as the ratio of the involved limb score and the uninvolved limb score expressed in percent-- LSI > 90% is usually used as a cutoff score for recreational and non-pivoting sports, whereas a >95% LSI for knee extensor and knee flexor muscle strength for the pivoting/contact/competitive athlete has been recommended. Uninvolved limb of ACLR is also significantly weaker to a matched limb of a control group. This implies that the LSI may underestimate strength deficits and argues for an implementation of absolute strength evaluation and not only limb symmetry—**LSI not a stand-alone measure for involved limb strength due to evidence of bilateral neuromuscular changes after unilateral injury.**<br><u>Hop Test:</u><br>Single hop for distance, triple hop for distance, triple cross-over hop, and the 6-m timed hop. Some concerns regarding the use of LSI and the uninvolved limb as a |

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| | | | | | | | reference for the involved limb. Athletes who have undergone an ACLR demonstrate bilateral deficits on hop tests in comparison to age- and sex-matched normative data of healthy controls. LSI >90% patients demonstrated significant and clinically relevant deficits in performance for both limbs when compared to normative data from healthy athletes. **LSI should not be used in isolation to evaluate functional performance changes** after ACLR, because it may **overestimate functional improvement, as a result of worsening contralateral limb function.**<br>Movement Quality Assessment: 60% of patients after ACLR had abnormal landing kinematics in the injured leg compared to their non-injured leg, although 72.3% of them passed the LSI > 90% criteria for hop tests. Between-limb deficits in eccentric and concentric loading parameters persist > 9 months after ACLR, indicating a compensatory offloading strategy to protect the involved limb during an athletic performance task. Greater asymmetry of trunk-side flexion, distance from center of mass to the knee and ankle in the frontal plane, pelvic tilt, and pelvic drop during unplanned change of direction was found for those |

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| | | | | | | | athletes who sustained second ACL injuries.<br>Other factor for RTS is psychological/ self-report readiness-- lower scores on self-reported knee function questionnaires were found in patients who did not RTS compared to patients who RTS.<br>RTS rehabilitation program supervised by strength and conditioning coaches over a period of 3 months in addition to the standard rehabilitation program incorporating **jumping and agility task**s was the most important factor to positively influence an RTS test battery—**rehab professionals work alongside S&C staff.** |
| 35. (48) | Combining plyometrics and isometric training to improve tendon stiffness and performance | Lum, D (2022) | Expert Opinion<br><br>Level 5 Evidence | Moderate-high | Expert opinion blog article | See conclusions.<br><br>**Importance of increasing both muscle and tendon stiffness concurrently to improve performance and reduce injury risk.**<br><br>**Examples of plyo-isometric contrasts in article.** | Mechanisms that enables SSC to enhance force generation and movement efficiency is the tendons storing and using elastic energy during muscle contraction-- stiffer tendon is able to produce greater recoil (force) when stretched to the same length as one that is less stiff. During the rapid eccentric phase, while the joint continues to move, the muscle remains relatively isometric. That allows the muscle to generate a large amount of force (greater stiffness) and facilitates the storage and recovery of tendon elastic energy. Compared to maximal force development, the rate of force development (RFD) is more closely related to many |

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| | | | | | | | sports-related movements—**ability to generate force quicker is better**. Tendon stiffness may influence RFD by affecting the time lag between muscle activation and muscle force production.<br>Plyometrics involve rapid SSC, the **muscles stiffen up and remain relatively isometric. The tendon, therefore, stretches to a longer length to store more elastic energy** that will be returned during the concentric phase. Performing plyometrics, then, essentially trains the muscles to maintain a greater level of stiffness. **Plyos= muscle stiffness.**<br>Exerting isometric force against a fixed object at the joint position where training occurs **increases tendon stiffness**, with longer contraction sustained having greatest effect. Need both in conjunction for power in SSC. Contrast training method to combine isometric and plyometric training in the training program—perform isometrics at the joint positions where the athlete initiates the concentric phase during the plyometric exercise. |
| 36. (49) | What is the Evidence for and Validity of Return-to-Sport Testing after Anterior Cruciate Ligament Reconstruction Surgery? | Webster, K (2019) | Systematic Review and Meta-Analysis<br><br>Level 1 Evidence | Moderate | Five databases (PubMed, MEDLINE, Embase, CINAHL, and SPORTDiscus) were searched to identify relevant studies and data were extracted regarding the number of patients who | Eighteen studies met eligibility criteria. Proportional meta-analysis showed that only 23% of patients passed RTS test batteries. One study showed that passing | 23% of patients passed RTS test batteries before return to sport.<br>For all knee injuries, there was no significant reduction in risk for those who passed RTS criteria--Passing an RTS test battery had minimal effect on reduction of the risk of all subsequent ACL injury. |

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| | | | | | passed the RTS test battery, as well as subsequent RTS rates and re-injury data when available. Results were combined using proportional and risk-ratio meta-analyses. | an RTS test battery led to greater RTS rates. Two studies showed passing RTS test batteries did not significantly reduce the risk of a further knee injury (risk ratio (RR)= 0.28 (95% CI 0.04–0.94), p = 0.09) and five studies showed that passing RTS test batteries did not reduce the risk for all subsequent ACL injuries (RR = 0.80 (95% CI 0.27–2.3), p = 0.7). However, passing an RTS test battery did significantly reduce the risk for subsequent graft rupture (RR = 0.40 (95% CI 0.23–0.69), p < 0.001], although it increased the risk for a subsequent contralateral ACL injury (RR = 3.35 (95% CI 1.52–7.37), p = 0.003].<br><br>**Current return-to-sport criteria do not appear to decrease the risk of subsequent anterior cruciate ligament (ACL) injury in** | Those who passed a test battery had a significantly reduced risk of a subsequent graft rupture. Passing the test battery significantly increased the risk of a subsequent contralateral ACL injury. RTS testing was typically conducted between 5 and 10 months post-surgery, with the most common time being 6 months—**necessitates need for patience and not rushing recovery process—increased emphasis on movement quality.**<br>Testing should be administered at multiple time points and once an athlete passes a test of the battery, that test pass requirement may be able to be dropped from the battery requirement. However, caution should still be exercised as athletes who pass a criterion at one time point may fail it at another.<br>**Only 29% of adolescent (15–20 years) patients achieved a limb symmetry index of > 90% on five tests of muscle function despite having already returned to strenuous sports at 8 months-- poor knee function combined with high exposure was a contributing cause of reinjury in this younger patient group**.<br>The test batteries have large floor effects.<br>**In terms of capability of return to play, passing an RTS test battery at 6 months post-surgery was shown to lead to** |

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| | | | | | | **athletes. Though passing return-to-sport criteria reduced the risk of subsequent graft rupture by 60%, it increased the risk of a contralateral ACL rupture by 235%.** | **significantly higher RTS rates at both 12 and 24 months.**<br>None of their young patient cohort was ready to return before 9 months.<br>ACLR RTS correlated to increased loading of the contralateral limb at the time of return to sport and beyond-- **accounts for the increased risk in contralateral injury post-release to return to play.**<br>RTS batteries can be used to provide the patient with important feedback with regard to their rehabilitation progress and may also, for example, boost confidence for when the patient returns to play. |
| 37. (50) | Periodization of ACL rehabilitation – Can we add something new? | Kakavas, G (2022) | Literature review blog article<br><br>Level 5 evidence | moderate | Blog article | See conclusions.<br><br>**Traditional rehabilitation is not capable to restore normal motor function in all patients after ACLR .Following an ACL tear, the CNS may increase its reliance on alternative sensory sources, such as visual-feedback and spatial awareness.** | Rehabilitation planned according to the periodization concepts should allow better integration of the needs of the patients to return to sport, using concepts which will be easily integrated with the sports and strength and conditioning coaches to ultimately benefit the athlete and prevent re-injury—**combined effort with S&C during ACLR rehab.** Concept of periodization has some growing points: Neurocognitive tasks, measuring reaction time, processing speed, visual memory and verbal memory, allow indirect assessment of cerebral performance. Situational awareness, arousal, and attentional resources may influence neurocognitive function, affecting |

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| | | | | | | | the complex integration of vestibular, visual, and somatosensory information needed for neuromuscular control.<br>An ACL injury induces changes to the central nervous system (CNS), given the loss of information from mechanoreceptors, pain and developed motor compensations--alters motor strategies.<br>Athlete should be progressively exposed to physical, environ-mental, and psychological stressors comparable to those to which they will be exposed to in their actual sport—**via motor control factors such as anticipation, responses to perturbation, and visual-motor control within complex task environmental interactions.**<br><br>**Restoration of symmetry alone is not sufficient to reduce the risk of re-injury. Focus should also be placed on addressing underlying deficits which likely contributed to the primary ACL injury.** |
| 38. (51) | Practical guidelines for monitoring decelerations: Time to speed up | Clubb, J (2022) | Expert opinion and literature review<br><br>Level 5 Evidence | Moderate | Blog article | See conclusions. | Many team sport actions occur at lower absolute speeds but require a high rate of change in velocity. These movements include accelerating, decelerating, and changing direction (COD). Efficient decelerations are highly ingrained in sports performance and on-field success. Given the frequency of cutting movements as an injury mechanism, |

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| | | | | | | | decelerations are often involved in an injury-inciting event. Deceleration mechanics influence the subsequent knee loading during a COD, and therefore, are a modifiable risk factor, particularly for anterior cruciate ligament injuries. They generate high-impact braking ground reaction forces, which may lead to neuromuscular and mechanical fatigue. Deceleration actions demand a greater biomechanical load compared to accelerations, and occur at a higher volume than acceleration actions. |
| 39. (52) | Groin Injury Prevention and Diagnosis | Serner, A (2022) | Blog article<br><br>Level 5 Evidence | Moderate-high | Expert opinion | See conclusions. | 90% of acute injuries involving the adductor longus. Many elements to consider when aiming to prevent groin pain. **Increasing adductor strength and capacity is probably the simplest and most effective**, though, as adductor-related groin pain is the most frequent presentation of groin pain. High load capacity exercises best practice**. Monitor loads, frequency and volumes in kicking sports as with any athletes.**<br>If we look to **injury mechanisms, we find the same diagonal pattern in skating as in kicking; with hip extension, hip abduction, and hip external rotation, followed by a rapid change to hip flexion and adduction--** places high loads on the adductor longus at long length, |

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| | | | | | | | so a similar approach likely goes for prevention |
| 40. (53) | DISASTROUS THINGS FOR YOUTH FEMALE ATHLETES | Suter, E (2022) | Expert opinion<br><br>Level 5 Evidence | Moderate-high | Expert opinion blog article | See conclusions. | Strength training gives female athletes' muscles the strength to handle the year-round load of organized sports.<br><br>Sports with similar movement patterns in the same season do not allow for adequate recovery.<br><br>Pushing through growing pains often necessitates longer recovery times than modifying and managing the loads—progressive overload.<br><br>Nutrition is vital, poor nutrition never allows muscles to get out of a catabolic state (breaking down), and it makes it hard for them to recover at their best so they can perform better the next competition. Under-fueling can also lead to hindered sleep, decreased focus and energy, and missed periods.<br><br>Recovery is two things: nutrition and SLEEP. Sleeping is the #1 aid for muscle recovery, as the majority of Growth Hormone secretion occurs to build muscles back up again from their catabolic state.<br><br>Expounding further, sleep enhances brain recovery so athletes can regain their focus, |

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| 41. (54) | Non-knee-spanning muscles contribute to tibiofemoral shear as well as valgus and rotational joint reaction moments during unanticipated sidestep cutting. | Maniar, N (2018) | Case control study<br><br>Level 5 Evidence | moderate | Eight recreationally active healthy males (age: 27 ± 3.8 years; height: 1.77 ± 0.09 m; mass: 77.6 ± 12.8 kg) volunteered to participate in this study. All participants had no current or previous musculoskeletal injury likely to influence their ability to perform the required tasks. All participants provided written informed consent to participate in the study. Ethical approval was granted by the Australian Catholic University Human Research Ethics Committee (approval number: 2015-11 H), and the study was carried out in accordance with the approved guidelines. | Muscle-derived joint moments showed excellent agreement with inverse dynamics based joint moments (R2, 1.0, IQR, 1.0 to 1.0; nRMSE, 3.2 × 10−3%, IQR, 1.5 × 10−3 to 1.1 × 10−2%; Fig. 1). The foot-ground contact model also showed acceptable results, with model-predicted ground reaction forces in agreement with experimentally measured ground reaction forces (R2, 0.95, IQR, 0.92 to 0.97; nRMSE, 7.9%, IQR, 6.1 to 10%). Additionally, once appropriate physiological delays were taken into account (100 ms corresponds to ~25% of stance phase), reasonable agreement was evident between the predicted muscle activations from the model and experimentally recorded EMG data | Anterior shear force of tib on femur was 218 N at initial contact, which gradually declined until switching to a posterior shear force at 46% of the weight acceptance phase. Greatest contributors to the posterior shear force were the biarticular hamstrings and soleus. The contribution of each of these muscles increased throughout weight acceptance. The anterior shear force was primarily produced by the quadriceps and gastrocnemius muscle groups. **The shift to a net posterior shear force at 46% of weight acceptance was mainly explained by a decline in the contribution from the gastrocnemius towards anterior shear, and an increase in the contribution from the biarticular hamstrings and soleus towards posterior shear.** Frontal Plane: Throughout weight acceptance, the gluteal muscles had the greatest capacity to oppose the valgus moment—glut Medius. Transverse Plane: The dominant contributors towards external rotation moment were the vasti (up to 23 Nm) and soleus (up to 10 Nm) muscles. The **gluteus maximus (2–10 Nm) and gluteus medius (4–5 Nm) muscles had the greatest potential to oppose** |

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| | | | | | | obtained from the current study as well as prior literature (Fig. 2). | **this moment (i.e. contribute to an internal rotation knee joint reaction moment) throughout weight acceptance.**<br>**Both knee-spanning and non-knee-spanning muscles contribute to the tibiofemoral reaction forces and moments during the weight acceptance phase of a rapid unanticipated sidestep cut—importance of CKC thought process for LEs.**<br>The soleus and gastrocnemius represent ACL agonists and antagonists—**don't forget to load the soleus—co-contractions lead to increase joint compression to resist TF translation.**<br>Gluteal muscle group is capable of generating a varus knee joint reaction moment, thus opposing (or controlling the magnitude of ) the net valgus knee joint reaction moment during the final 25% of weight acceptance of sidestep cutting—**glut med to resist frontal plane forces (CKC model).**<br>injury prevention strategies should focus on optimizing the function of the hamstring muscle group, as the biceps femoris long head and medial hamstrings were shown to be the two primary contributors to posterior shear during weight acceptance of sidestep cutting. The function of the soleus would also seem important, due to this muscle's contribution to the posterior shear knee joint reaction |

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**Via Portney Table 36-1: Summary of Levels of Evidence (2020).

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